Control ENGINEERING

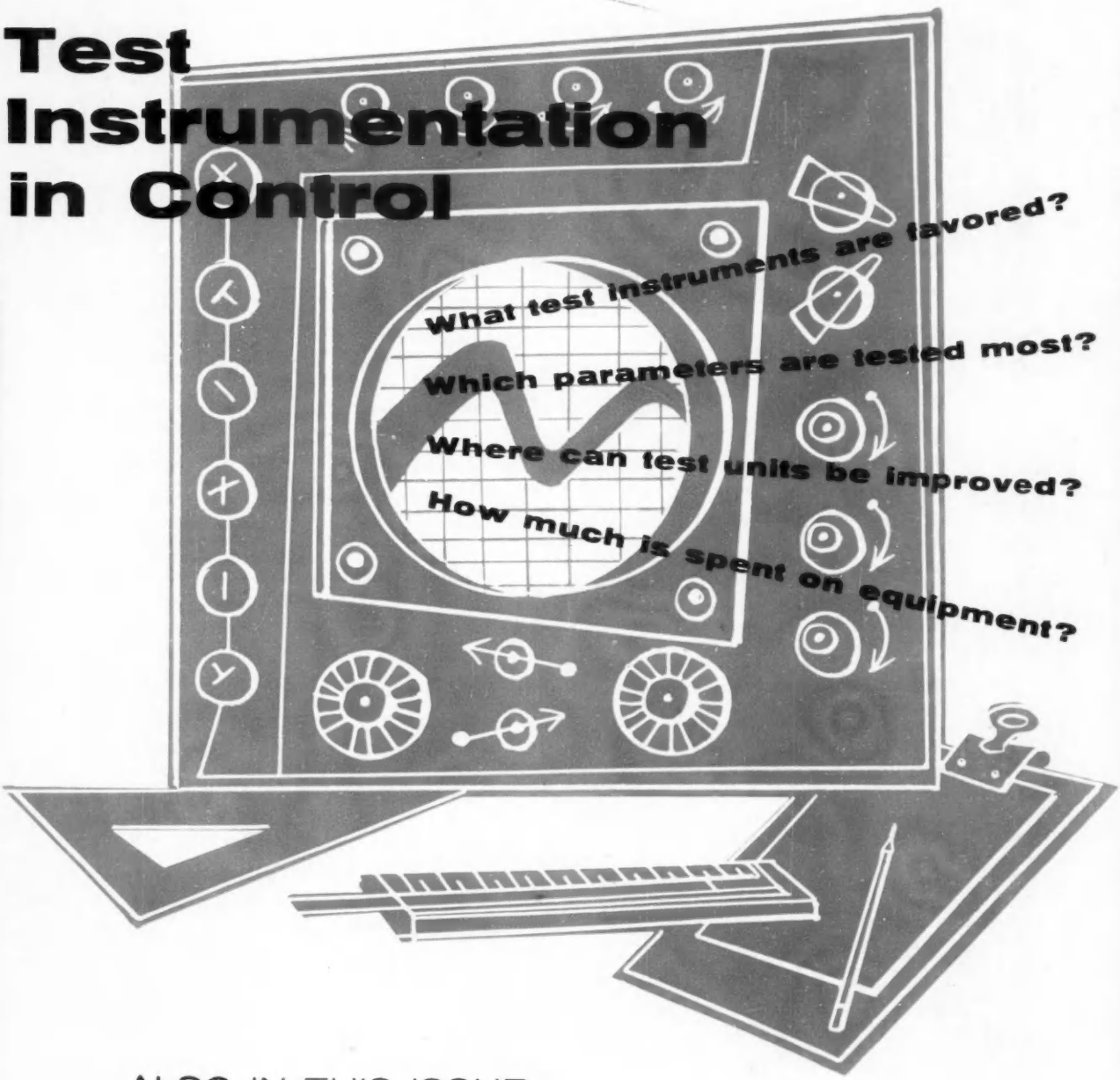
INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

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PRICE 50 CENTS

MARCH 1957

Test Instrumentation in Control



ALSO IN THIS ISSUE:

Selecting Nuclear Reactor Instruments

High Performance from a Low Cost Servo

Automatic Generator-Line Matching

Librascope

positive mechanical drive XY Plotters

for greater accuracy in graphic data recording



MODEL 200-A for resistance inputs

LIBRASCOPE'S UNIQUE "FLOATING GEAR TRAIN," *and conservatively rated conventional vacuum tube and harness circuitry result in static accuracy of 0.1% and dynamic accuracy within 0.5% of full scale, at a tracking rate of 5 inches per second.*

The Librascope Models 200-A and 200-B XY Plotters are engineered for accuracy, rapid response, and ease of operation. The positive mechanical drive of the Floating Gear Train eliminates lost motion, cable stretching or alignment adjustments, normally found in the cable tape or lead screw type of drive. The new, simplified plotting pen of one-piece design—used for point or continuous plotting—eliminates bottles and tubes—permits rapid changing of ink colors. Easy to load and always visible, the plotting table accepts paper up to 11" x 17". Point plotting or curved tracing is accomplished with equal ease with one-second full scale response. A variety of input accessories are listed below.

Control panel configuration of MODEL 200-B for DC signal input

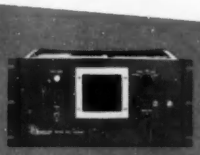
MODEL 200-A can utilize any external resistance potentiometer as an input transducer associated with each axis. Independent 10 to 1 scale expansion and origin positioning controls are provided. Facilities for external control of the pen drop solenoid and for simultaneous control of external equipment through switch closures, are provided.

MODEL 200-B, used for DC signal input, has full-scale sensitivities of five millivolts and an input impedance of 1,000 megohms in the millivolt scale ranges. Drift-free operation is assured by chopper-stabilizing the voltage inputs against an Epply standard cell reference.



READILY ADAPTABLE FOR RACK MOUNTING

Librascope XY desk model plotters are readily adaptable for mounting in standard RCA and RMA racks, for which accessory hardware is available at slight extra cost.



LIBRASCOPE PUNCHED CARD CONVERTER

Provides for the conversion of data read from IBM punched cards into analog signals that the MODEL 200-A Plotter can accept as inputs.



LIBRASCOPE PUNCHED TAPE CONVERTER

Converts the digital information read from punched paper tape into electrical signals suitable for the control and actuation of a MODEL 200-A Plotter.



LIBRASCOPE X-Y DECIMAL KEYBOARD

Consists of three-decimal bank for each axis with associated plus minus keys. Features Librascope designed positive-action self-wiping contacts.



LIBRASCOPE BINARY CONVERTER

Translates X and Y coordinate information received in the form of binary signals into analog signals for automatic point plotting by a MODEL 200-A Plotter. Has a capacity of nine binary digits and a resolution of one part in 512.

Career opportunities exist at Librascope for qualified engineers, physicists and mathematicians. Learn about Librascope's new "Creative Project Development Teams." Contact Glenn Seltzer, Employment Manager.

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Chances are the day-to-day solution of *your* design and process control problems has given you a pretty exact idea of what *you* require in analog computing equipment. Chances are, too, that you've been unable to find production computers which just fill the bill. Well, here's the answer to your problem. It's the spectacular GEDA A-14 Series Goodyear Electronic Differential Analyzer.

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Take, for example, these 3 exclusive servo units:

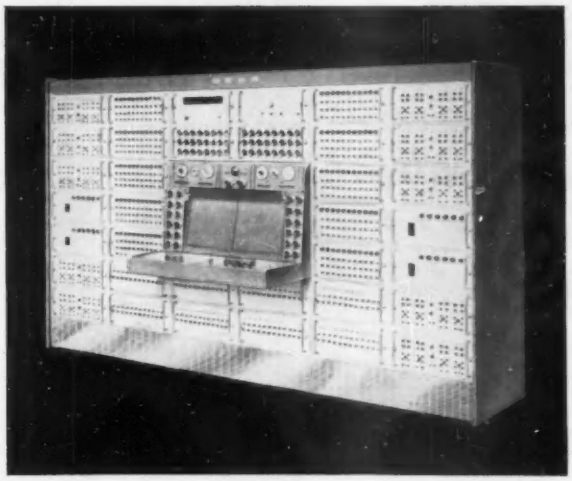
1. High Speed Servo Multipliers on the A-14 eliminate the noise, expense and trouble of a 400 cycle AC power supply, for the A-14 servo motors are DC. Requiring no input choppers or output transformers, the A-14 servos increase reliability and decrease maintenance costs. The high current-low voltage characteristics of DC motors allow the use of transistors, eliminating many troublesome vacuum tube power output stage problems.

2. Servo Function Generators on the A-14 have two linear and four tapped potentiometers. Four plug-in loading cards adjust to set each function and may be stored for future use. The A-14 Servo Function Generators not only produce the function, but also the product of the function and a variable.

3. Servo Resolvers on the A-14 may be used for both inverse and direct resolution and include AGC for high performance operation in inverse resolution application. Another available unit permits electronic integration while generating sine X and co-sine X from dx/dt thus providing continuous resolution.

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In addition to the 28 volt models featured at the right, the following units are also available:

OTHER 28 VOLT MODELS

Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
28-5VPM	0-32 V	5	20% (24-32 V range)	115 V 1 phase	2%
28-10WX	24-32 V	10	±½%	100-125 V 1 phase	1%
28-15VPM	0-32 V	15	20% (24-32 V range)	115 V 1 phase	5%
28-50WX	24-32 V	50	±½%	230 V* 3 phase	1%
MR2432-200	24-32 V	200	±½%	230 V* 3 phase	1%
MR2432-300	24-32 V	300	±½%	230 V* 3 phase	1%
MR2432-500	24-32 V	500	±½%	230 V* 3 phase	1%

*±10%. Also available in 460 V ±10% AC input. Will be supplied with 230 V input unless otherwise specified.

6, 12, 115 VOLT (NOMINAL) MODELS

	Model	Volts	Amps	Reg.	AC Input (60 cps)	Ripple rms
6 Volt	6-5WX	6 ±10%	5	±1%	95-130 V 1 phase	1%
	6-15WX	6 ±10%	15	±1%	95-130 V 1 phase	1%
	6-40WX	6 ±10%	40	±1%	95-130 V 1 phase	1%
12 Volt	12-15WX	12 ±10%	15	±1%	95-130 V 1 phase	1%
115 Volt	115-5WX	115 ±10%	5	±½%	95-130 V 1 phase	1%
	MR15125-C	15-125	5	±1%†	95-130 V 1 phase	1%†
	6125-25**	115-125	25	1½-4%	230/460 V 3 phase	5%

**Germanium Rectifier Unit †Increases to 2% @ 15 V.

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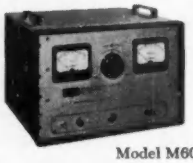


Model MR532-15A

2-36 VOLTS @ 15 AMPS SPECIFICATIONS

Regulation:	5-32 Volt Range: ±½% 2-5 Volt and 32-36 Volt Range: ±2%
AC Input:	105-125 Volts, (for 2-32 V.DC), 110-125 V, (for 32-36 V.DC), 1 phase, 60 cps (8 amps)
Ripple:	1% rms max. (@ 36 volts and full load. Increases to 2% @ 2 volts and full load).

Remote Sensing • Vernier Control



Model M60V

0-32 VOLTS @ 25 AMPS SPECIFICATIONS

Regulation:	±1% @ 28 Volts (Regulation increases to 2% over range of 24-32 volts; does not exceed 2 volts over 4-24 volt range. Not stabilized for AC line changes.)
AC Input:	115 Volts, 1 phase, 60 cps (12 amps).
Ripple:	1% rms (@ 32 volts and full load—2% rms max. @ any voltage above 4 volts).



Model MR1040-30A

5-40 VOLTS @ 30 AMPS SPECIFICATIONS

Regulation:	±1% (over entire 5-40 volt range)
AC Input:	100-130 Volts, 1 phase, 60 cps
Ripple:	1% rms



Model 28-30 WXM

24-32 VOLTS @ 30 AMPS SPECIFICATIONS

Regulation:	±½%
AC Input:	100-125 Volts, 1 phase, 60 cps (20 amps). (Unit rated for DC output of 28 volts ±10% for 95-130 volt input.)
Ripple:	1% rms



Model MR2432-100XA

24-32 VOLTS @ 100 AMPS SPECIFICATIONS

Regulation:	±½%
AC Input:	208, 230 or 460 Volts, ±10%, 3 phase, 60 cps (14, 12 and 6 amps respectively). 230 volt input will be supplied unless otherwise specified.
Ripple:	1% rms

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Control ENGINEERING

MARCH 1957 VOL. 4 NO. 3

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS
Published for engineers and technical management men who are responsible for the design and application of instrumentation and automatic control systems.

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The picture on the left was snapped as Don Campbell lectured to the International Congress on Automation in Paris last August, five months before his untimely death. His topic in Paris: the mathematical foundations underlying the systems approach (see October '56 issue, page 32). In the fall months that followed, Don vigorously criss-crossed northern Europe spreading his gospel as a consultant and educator. On his return to Boston in early December he suffered the first of two heart attacks which were to prove fatal on Jan. 15. With a deep sense of loss we pay our tribute to Don in this month's Editorial on page 85.

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Bulova's experimental frequency sorter uses unique jig to feed crystal blanks between 2 electrodes, an oscillator in a tank circuit with the crystal, and a Berkeley 5571 frequency meter to give precise digital reading of frequency.

Doing a day's work in 12½ minutes!

Mechanizing military crystal production posed plenty of problems for Bulova Research and Development, Inc. The Signal Corps wanted 50,000 crystal blanks a day processed, a sizeable increase over the 1500 a day by current techniques.

From the experimental setup pictured above, they developed an automatic frequency sorter with a capacity of 2 blanks per second, or 1500 in 12½ minutes, (now being built by Berkeley Systems Engineering group). Tolerance is 0.005% of normal frequency, range is 4 to 54 mc.

Without the Berkeley 5571 frequency meter as a basis, this development would not have been possible. The services of Gawler-Knoop, Berkeley's engineering representative in the New York area, were equally invaluable in making this 5571 application and subsequent service a success for Bulova.

If your work involves measurement of frequency ratio, frequency period, or frequency from 0 cps to 1100 mc it will pay you to investigate the versatile 5571—the meter that literally "grows with the job."

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Kennard and V. C. McIntosh of WRIGHT AIR DEVELOPMENT CENTER Install Magnetic Tape Recorder in F-101 Aircraft.

Dynamics Section, Engineering Support Branch at Wright Air Development Center's Equipment Laboratory is primarily responsible for evaluating aircraft equipment under conditions of actual use . . . particularly vibration, shock, and acceleration. Under Section Chief D. C. Kennard, it records these phenomena as they actually exist in aircraft and missiles under all conceivable service conditions.

Prior to 1952, 12-channel recording oscillographs were used. But weight and size limited their use, as did the need for an operator to set attenuators for optimum sensitivity on each channel. Furthermore, the Dynamics Section is particularly interested in the frequency content of vibration, and the relative amplitude of each component frequency. But getting this information from oscillograph traces proved something of a problem. Visual examination was neither accurate nor complete. The Section resigned itself to using the 24-point method of Fourier Analysis in conjunction with punched card equipment, but was far from satisfied.

Searching for an entirely new approach, the Dynamics Section settled on magnetic tape recording, despite the fact that no suitable equipment was in existence. On November 2, 1949, in Exhibit MCREXE84-2, The Air Force called for the development of airborne magnetic tape data recording, reproduction and analysis equipment.

Among the responses to the exhibit was a proposal from the Davies Laboratories, Inc. Though the company had no previous experience with tape or recording, the ideas which Gomer L. Davies set forth in that proposal were interesting enough to gain his company the contract. Let on April 7, 1950, it called for three 14-channel airborne recorders, a 14-channel ground playback unit, and a dual channel automatic wave analyzer.

The combined efforts of Davies and his staff, and the Dynamics Section overcame obstacles that for years had chained magnetic tape to the broadcasting studio. The first system delivered to the Dynamics Section included such refinements as servo speed control for correcting low-frequency tape speed variations and a unique, completely elec-

MAGNETIC TAPE data recording Born: April 7, 1950

Today, magnetic tape is an accepted tool for data acquisition, processing, and storage. It has proved its worth in laboratories, industrial plants, even missile test centers. But a decade ago magnetic tape data recording did not exist. And without the inspired cooperation of a government agency and a private enterprise, it might not exist yet.

tronic compensation system for eliminating the effects of wow and flutter.

By 1952 magnetic tape data recording was a reality, with the delivery and acceptance of the first complete system for airborne use in November.

Substantially all the requirements set forth in the 1949 exhibit had been met. And several had been exceeded. The completely self-contained recorders were even smaller than specified. The three recorders so speeded up data acquisition that The Air Force immediately placed an order with Davies for four additional channels of analysis equipment.

With the introduction of magnetic tape data recording in November, 1952 as a full grown art, the technique was quickly adopted in laboratories, manufacturing plants, and government installations across the country . . . an amazing growth. But the record set by Davies equipment at Wright Air Development Center is impressive enough in itself. Davies recorders have been used there in testing every conceivable kind of aircraft, including:

F-86A F-86D B-36 B-45 B-47 B-50 B-52 B-57 B-66 C-47 C-54 C-123 C-124 C-130 H-19 KC-97 Q-2A RB-50

They have been used for ground testing at least ten different power plants. They have been taken to other military installations so that data recorded there could be analyzed on Davies equipment at the Dynamics Section. Most important, data made available by Davies equipment assisted in causing revisions in basic Air Force Specifications. It has been possible to prove, for example, the importance of high frequency vibration as a vital design consideration, and thereby eliminate an arbitrary upper limit of 55 cps on vibration testing.

Surely, magnetic tape data recording has been proved a development of vital importance. But it has even greater significance as an outstanding example of the benefits of a country in which government and industry can work hand-in-hand . . . cooperating on every level for the eventual betterment of all mankind.



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SHOPTALK

By takes the reins . . .

It's hard to see how, but By Ledgerwood will soon be busier than ever. Starting with the April issue By takes up the reins as Managing Editor. And even though he'll be on a full-time job of managing and planning, he expects to find time to continue roaming the field to keep abreast of his two "pet" interests: machine tool control and servo-technology. At the same time, two new Associate Editors join to bolster the staff for hard-driving By. They are:



. . . John gets into harness . . .

John Cooney, who comes to us fresh from five years as an Associate Editor of *Electrical Manufacturing*. A specialist in articles on the design and application of motors and controls to machines and equipment, John will take on many of By's former productive assignments. An EE grad from Manhattan College, our new Associate has field experience in designing control systems and is a former McGraw-Hill editor.



. . . Lew tests the track . . .

Lew Young, former Information Representative of Westinghouse's Atomic Power Div. Associate Editor Lew will be our star technical reporter—he'll scour the field for new developments for *What's New*, *Pulse*, and feature articles on outstanding systems. An ME grad from Purdue, Lew also has publishing experience as a McGraw-Hill editor; in fact, he was one of the pioneer band who put out the pilot (Jan. '54) issue of CtE.



. . . Lloyd goes into the grandstand . . .

This issue marks the last official one for Lloyd Slater as Managing Editor. On Feb. 15 Lloyd left his typewriter and schedule board to become Executive Director of the newly formed Foundation for Instrumentation, Education & Research (see Dec. CtE, page 79). As a spectator and loyal reader (we hope), Lloyd should be eminently qualified to send peals of negative feedback at us from his ivory tower. We'll look for his letters—and tremble before his visits.





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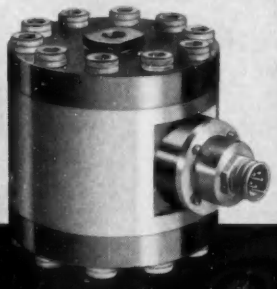
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For additional data, please request Bulletin Nos. PL80TC and PM80TC

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FEEDBACK

Omnia Gallia in partes tres est divisa—control engineering, automation, and analog computation. Will the Comité International Provisoire de Regulation et d'Automatisme integrate them? Ed.

To the Editor—

You have asked Mr. Raymond or myself to inform you on the position in this country in what concerns international cooperation in the field of automatic control, on one hand, and automation or cybernetics, on the other hand. Here is what I can state on my behalf.

In last June Mr. Raymond attempted, as chairman of the International Congress of Automatics held in Paris at that time, to create an international committee for automatics. This idea—supported by some few foreign delegates (Mr. Raymond claims that amongst them was Dr. Donald P. Campbell)—has not yet given the least definite result yet.

Before this congress, a Society for Control Engineering named AFRA (Association Francaise de Regulation et d'Automatisme) was created in France. It has been formed by the six most important French societies of engineers, namely the Societe des Ingenieurs Civils de France, the Societe Francaise des Electriciens, the Societe Francaise des Radio-Electriciens, the Societe Francaise des Mecaniciens, the Societe de Chimie Industrielle, and the Groupement pour l'Avancement de la Mecanique Industrielle. The chairmen of these six societies are members of the board of the AFRA and nobody can be an active member of the latter unless he is a member of one of these societies.

The chairman of AFRA is Professor Veron and I am one of its vice- presidents (the other one, Professor Esclangon, being unfortunately deceased since and having not yet been replaced). Amongst the 27 members of the board, a small minority (five: Mr. Raymond, Mr. Naslin, Mr. Chalvet, Mr. Gardelini and Mr. Chevillotte), all of whom are either theoreticians of servomechanisms or production experts (economists), seem to form a group with very characterized separatist tendencies, directed toward automation. Up to this day, however, they have not created any other society and still remain in AFRA.

On the other hand, Mr. Raymond is one of the directors of the International Society for Analog Computation in Brussels, the chairman of which is Professor Hofmann; the latter is simultaneously vice president of the IBRA (Institut Belge de Régulation et d'Automatisme), which is the Belgian society corresponding to AFRA in France.

As you also know, the Heidelberg

To the Editor—

I understand from your letter that our American friends are taking under consideration our traditions of international cooperation in the field of automatism and cybernetics. Unfortunately, so far as I am concerned, things do not appear very simple.

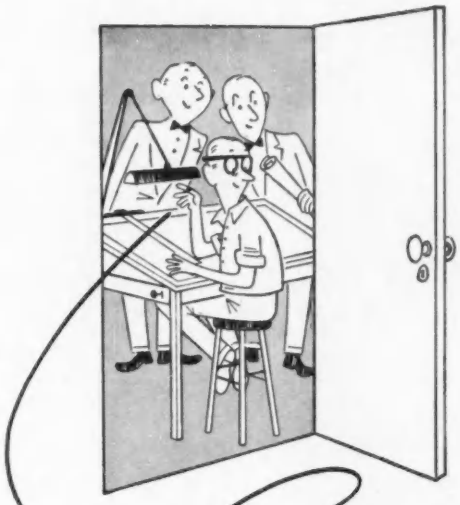
An initial project was initiated as a result of the Congress International de l'Automatique organized at the Conservatoire National des Arts et Metiers in Paris, and of which I was the president of the Committee on Organization. This project set up an international committee for liaison and organization of congresses, exchange of information, of visits. . . .

Then in Heidelberg the vice-president, Mr. Broida [whose letter begins in the column at the left] of the Association Francaise de Regulation et d'Automatisme, took a different position. [See CtE, Dec. '56, pp. 32-33, for resolution to establish an international federation of control engineering]. Personally, I abstained from bringing about realization of the June 1956 project, in order that the Association Francaise de Regulation et d'-Automatisme may take its chances. It is my feeling that this association is too young and has too few members to be able to succeed in such an undertaking. But that is my opinion.

During the week of Dec. 18 the Association Francaise de Regulation et d'Automatisme met, in limited assembly, with persons from some European countries. I would have joined in this meeting, with the representatives of the AFRA, but since I am not in agreement with the projects to be dealt with there, I did not.

I shall not fail, should I have the opportunity, to mention that your magazine contributes to an international association in its field.

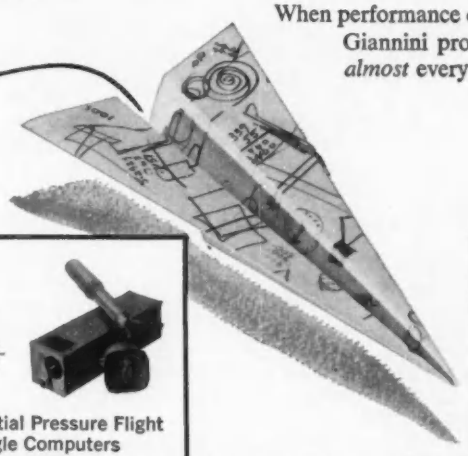
F. H. Raymond
Saint-Germain-en-Laye, France



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Accelerometers



Temperature Probes

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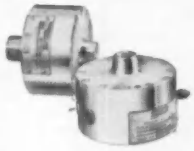
Gyro Instruments



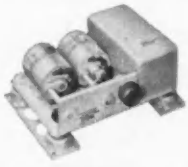
Infinite Resolution Spiralpot Potentiometers



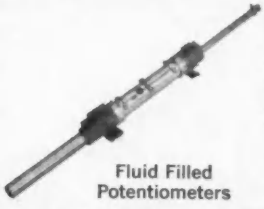
Aerodynamic Angle of Attack Transducers



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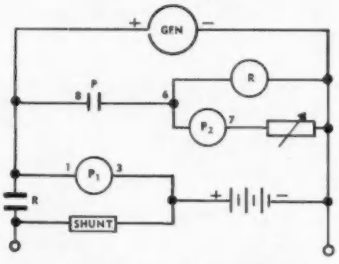
THE MARK OF QUALITY
BARBER COLMAN

ultra-sensitive relays

HELPFUL DATA FOR YOUR CIRCUITRY IDEA FILE . . .

(No. 4 in a series by Barber-Colman Company)

The circuit drawing below indicates just one of the hundreds of ways many manufacturers are utilizing Barber-Colman Micropositioner ultra-sensitive relays to solve complex control problems. Could this be the answer to some of yours, too?



BATTERY REVERSE CURRENT DETECTOR

Among the many applications for the Barber-Colman Micropositioner in the railroad and industrial fields is that of reverse current protection between the generator and battery on diesel locomotives and industrial trucks. In the circuit illustrated, the Micropositioner, P_1, is energized when the generator voltage exceeds the battery voltage by approximately one-half volt. A secondary relay, R, connects the generator to the battery and simultaneously energizes an auxiliary coil, P_2, on the Micropositioner which aids the main coil in holding the contact closed until a predetermined amount of reverse current is flowing from the battery. The point of drop-out is controlled by the variable resistor in series with the auxiliary coil. This system offers accurate control of the points at which the generator is connected and disconnected from the battery, thereby eliminating unnecessary discharging of the battery or hunting between generator and battery control.

If your projects involve similar types of control, why not make a test with a Micropositioner engineered for circuits similar to that shown above? Write for technical bulletins F-7279 and F-3961-6.



BARBER-COLMAN MICROPOSITIONER POLARIZED DC RELAYS

Various types . . . plug-in, solder-lug, screw terminal, hermetically sealed. Operate on input powers of 40 to 1,000 microwatts for use in photoelectric circuits, resistance bridge circuits, and electronic plate circuits. Send for data.

BARBER-COLMAN COMPANY
Dept. O, 1848 Rock Street, Rockford, Illinois

FEEDBACK

Congress had led to the resolution signed by delegates of 18 countries and to the foundation of a Provisional International Committee of six members who are Professor Oldenburger (U.S.A.), Professor Letov (Russia), Professor Nowacki (Poland), Dr. Grebe (Germany), Mr. Welbourn (United Kingdom) and myself (France). I have been elected chairman of this Provisional Committee, the secretary of which, Dr. Ruppel, is in Dusseldorf (Germany).

It has been decided, with the agreement of Professor Oldenburger, that while the Provisional Committee will work on the formation of the International Federation and call up the first General Assembly of the latter as soon as a sufficient number of countries join it, a restricted meeting of representatives of such countries which already have an unique Control Engineering and Automatics Society will be held in Paris. The meeting took place on Dec. 18 and 19 and grouped representatives of France, Germany, Switzerland, Belgium, Holland, and Norway. Of course, this meeting did not intend at all to compete in any way with the International Federation in course of formation; all on the contrary, its aim was to start at once some definite jobs (such as international standardization of vocabulary, of block diagrams, of methods of filing data on control engineering and automatics, etc.) which should be taken over later on by the International Federation as soon as it is formed.

It is perhaps this meeting in Paris which has led to erroneous information on the activity afoot in France to set up any new international society, whilst in fact it is entirely in the limits of the Heidelberg resolution. On the other hand, the trend of some few individuals in France towards an activity separated from that of the AFRA (which has officially joined the future International Federation on the foundation of which the Provisional Committee is working) can, of course, lead to some international developments, as the same trend exists outside of France (namely in Belgium with Professor Hofmann and his assistants Mr. Willems and Mr. Peretz and, perhaps, in Great Britain). But such an eventual activity seems to me quite negligible when compared with that of the supporters of the Heidelberg resolution in all countries. The latter continue to believe that there is no serious reason to separate automatic control from automation, as a small minority of engineers (at least, in France) would like to do.

Dr. Victor Broida
Boulogne-Sur-Seine,
Seine, France

Equations for business feedback?

To the Editor—

I am a project engineer versed mainly in tooling, gaging, and production methods. During the past two years I have also endeavored to acquire some fundamental understanding of data processing and system control techniques, having previously been exposed to only basic electronics. As a word of appreciation I would like to say of CtE that the real significance and value is in the not-too-technical presentation beamed at the not-too-initiated readers. I refer to the easy-to-read "basic" and "application" series on digital and analog computers.

In the nonphysical realm where measurement and definition is out of question I am at a loss to understand how the equation can bridge the deep gulley between a highly integrated process of *production* and hit-or-miss end-product *distribution*. Management-science will face some extremely difficult situations when dealing with the many unrealistic factors related to our political and price system operation.

We may assume the situation tem-

Foreign exchange may help you

We have received a letter from the publisher of "Philips Technical Review" stating the availability and prices of periodicals he publishes in addition to the "Review". Here is the list:

Title	Issues	Price	Subscription period
Philips Research Reports	6	$5	January-December
Communication News	4	3	irregular
Philips Serving Science and Industry	6	3.50	January-December
Medicamundi	4	3	January-December
Electronic Applications	4	4	July-June

If interested, contact: Th. Vervoort, Techn. & Scient. Lit. Dept., N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands.

porary, but doesn't it present timely topics for open discussion?

George Pavlik
Detroit, Mich.

Yes, responds inner loop

To the Editor—

Considerable work is in progress covering production scheduling, inventory control, transportation, and distribution problems, both in industrial and governmental agencies. Many of these activities fall in the realm of operations research.

Production scheduling is concerned with setting up the flow of materials and with the utilization of manpower, machines, and other facilities in order to produce a product at a given date. For job-shop-type operations, mathematical formulation of the production scheduling has already been accomplished. Large savings have been made in improving all of the above mentioned factors. The problem of optimizing production scheduling is more difficult since there are many influencing factors.

In inventory control there are problems which become very closely associated with distribution. Ramo-Wooldridge has recently worked out and applied a mathematical formulation for the warehousing of automobile replacement parts. The technique involves representation of customer demand, inventory levels, and replenishment times — all statistical quantities. It also involves measurement of these quantities in practical cases and determination of lost sales due to shortage of parts. In the case cited, a redistribution of the type of inventory carried with no increase in inventory dollars changes the lost sales from 14 percent to 10 percent. This represents increased sales of about $1 million with no additional labor, data processing, or storage facilities. The solution was by the Monte Carlo method using a large-scale digital computer.

Probably some of the most forward-looking activities concerning distribution are the armed services projects concerning distribution and supply. It is likely that much of the experience and know-how gained on these projects can be applied to business.

E. M. Crabbe
La Canada, Calif.

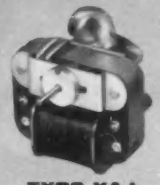
The problem of introducing new scientific methods and tools to management is, indeed, long term in nature. It is important to encourage those who are actively engaged in promoting the utilization of scientific techniques by management and who are interested in clarifying concepts

THE MARK OF QUALITY

BARBER COLMAN

Small Motors





TYPE YAJ

"This motor assures precision timing of our new Massa Recorder"

Ernest A. Massa, Vice-President, Massa Laboratories, Inc., Hingham, Mass.

The new Massa Recorder makes accurate ink records of high-speed electrical signals on a moving paper chart with a jeweled-bearing linkage design producing true rectilinear motion of the pen tip. Acoustic damping of the drive coil eliminates resonance peaks in the response, thus making the instrument a true recording milliammeter independent of special compensating amplifiers. To realize the full wide-range recording capabilities of this new instrument, Massa Laboratories chose a Barber-Colman YAJ Synchronous Motor which assures high precision along the timing axis of the chart and permits compact design of the instrument. If you have a design problem involving small motors, let Barber-Colman engineers help you solve it with the exact motor for the job.

FREE HELPFUL DATA SERVICE on the complete line of Barber-Colman small motors which includes unidirectional, synchronous, and reversible motors — up to 1/20 hp. With and without reduction gearing — open or enclosed types. Expert engineering service available. Write today, tell us your problem, ask for free data sheets and catalog F-4271-6.



REVERSIBLE



SYNCHRONOUS



GEARED



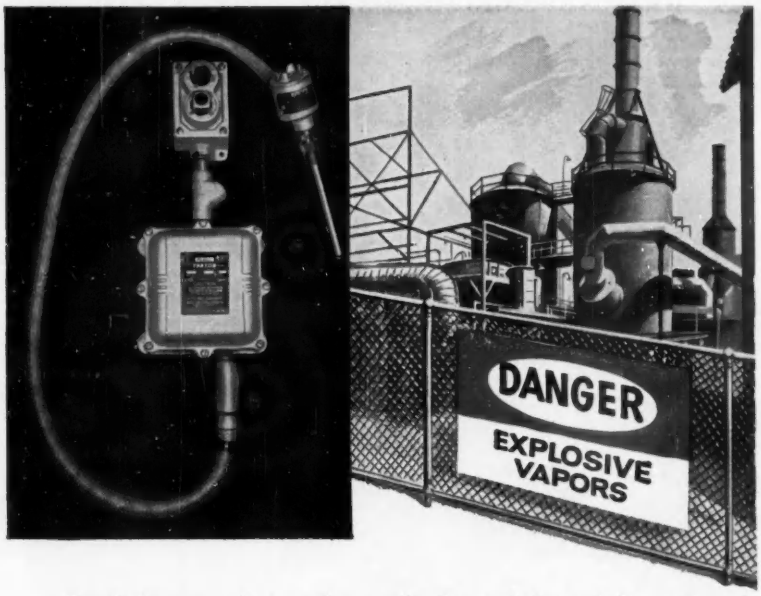
UNIDIRECTIONAL

BARBER-COLMAN COMPANY

Dept. O, 1248 Rock Street, Rockford, Illinois

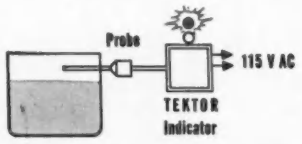
Small Motors • Automatic Controls • Industrial Instruments • Aircraft Controls
Electrical Components • Air Distribution Products • Overdoors and Operators
Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

TEKTOR® Electronic Level Control safe for hazardous locations



Practically every plant can improve level control electronically—and meet safety requirements—now that the entire Fielden TEKTOR System is UL listed and FM approved for Class I, Groups C and D, and Class II, Groups E, F and G, hazardous locations.

This explosion-proof unit features a specially-designed ferralloy housing and Teflon* insulated probe. Available for fail-safe high or low level control, it features the same simple and versatile capacitance circuitry found in the standard TEKTOR unit.



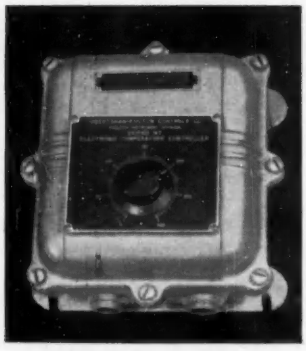
As level changes, capacitance at the probe also changes and energizes a relay. TEKTOR flashes a warning and can operate controls to keep level from exceeding desired limit.

*Trade-mark for Du Pont tetrafluoroethylene resin.

TEKTOR features

- Controls level of liquids, liquid interface, powders, granular solids (conducting or non-conducting)
- Responds to changes as small as 1/16" in aqueous solutions
- No moving parts—only one radio tube

NEW EXPLOSION-PROOF TEMPERATURE CONTROLLER



Fielden's sensitive Series 97 Controller is now available in explosion-proof design for hazardous locations. Used with resistance temperature detectors, this controller actuates two-position control devices with changes as small as ±0.2° F. Ranges from −330° F. to +1382° F. Lamps show whether temperature is above or below control point setting.

Write for literature

Robertshaw-Fulton CONTROLS COMPANY

FIELDEN INSTRUMENT DIVISION

Dept. S, 2920 N. 4th St., Philadelphia 33, Pa.

FEEDBACK

and methods so that management can better understand them. Those interested in these problems should take part in the activities of organizations such as The Institute of Management Science or the Operations Research Society of America. Ed.

Let's put the record straight

TO THE EDITOR—

In your column *What's New*, (page 160 of CONTROL ENGINEERING for October 1956) your announcement states: "Paul W. Koch was hired away from his Baldwin-Lima-Hamilton post, etc. . . ."

Your column editor's choice and use of the phrase "hired away" is unfortunate in that it most inaccurately describes the circumstances of Mr. Koch's change from his former employ to the present one. Records show clearly that Mr. Koch left Baldwin-Lima-Hamilton in May. It was not until July that we entered even exploratory talks with Mr. Koch concerning the possibility of his joining A. C. Ruge Associates, Inc. In light of these facts the phrase you use—"hired away"—becomes false and misleading.

Arthur C. Ruge
Cambridge, Mass.

Deep apologies to all concerned. The choice of the phrase "hired away" was an unfortunate and inaccurate one. Ed.

Floating decimal overextends truth

TO THE EDITOR—

I have to take exception to printed version of my statement [at the Philadelphia Symposium on Data Loggers (CtE, Jan. '57, p. 21)] concerning the cost of adding "online" computation to a logger, on page 38. My statement was that we feel that the cost of a 500 point system would be increased by about 20 percent. The printed version states that a computer would "up the cost of a 50,000 point logger by roughly 2 percent". I believe that your typesetter over-extrapolated the curve past the point of validity although the statement, as printed, may be true when the market for 50,000 point systems increases a bit more. At present, I suspect this market is close to zero.

Arthur Freilich
Burroughs Corp.
Paoli, Pa.

NEW! ultra-stable FM Telemetering Discriminator*



**Epsco Model FM-108 FM-to-Voltage Converter.*

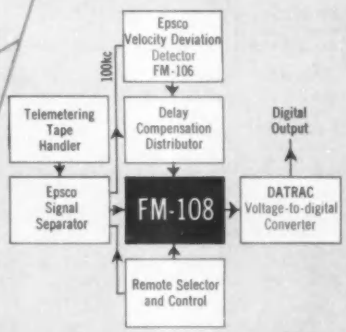


EPSCO'S MODEL FM-108 crystal-controlled ultra-stable, all-channel discriminator presents a new *standard of accuracy* . . . better than an order of magnitude more accurate and stable than any other commercially available equipment . . . and with absolutely *no* adjustments! This new standard of FM data processing features:

- **HIGH DYNAMIC ACCURACY:** Absolute accuracy is better than 0.05%, and the dynamic accuracy of the equipment from input to associated band-pass filter through the low-pass output filter is better than 0.2%.
- **LONG-TERM STABILITY:** 0.2% for life of equipment with no adjustments for zero drift, gain and line voltage variations, etc.
- **VERSATILITY:** Converter operates on any of 23 standard IRTWG telemetering sub-carrier frequencies from 400 cps to 70kc. Band switching may be accomplished remotely or by selector switch on front panel.
- **AUTOMATIC WOW and FLUTTER COMPENSATION:** With Epsco FM-106 Velocity Deviation Detector and Epsco CD-601 Velocity Deviation Compensation Distributor, errors from tape speed variations are reduced by a minimum of 35 db.
- **ZERO and 100% DATA CORRECTION:** Produces automatic compensation for variation of transmitting sub-carrier oscillator frequency and gain by a transistorized electro-mechanical servo feature.
- **DYNAMICALLY ACCURATE SELECTABLE LOW-PASS FILTERS:** A 5-pole filter utilizing precision wire-wound resistors and ultra-stable polystyrene capacitors in combination with chopper-stabilized d-c amplifiers provides:
  - Phase linearity deviation not exceeding 0.25 degrees over 90% of bandwidth.
  - Pass band flat within ±0.1% (0.01db) to F_c.
  - Minimum attenuation of 54 db of nearest beat frequency between sub-carrier channels.
  - A total of 62 different low-pass filter bandwidths selectable from 11 cps to 3490 cps.
- **PHYSICAL CHARACTERISTICS**

  SIZE: 10½" of space of standard 19" cabinet.
  WEIGHT: 29½ pounds.
  CONSTRUCTION: Constructed of 8 separate plug-in chassis assemblies containing electronic and magnetic components. All components are accessible on the standard layout forms.

Engineering data sheet available on request.



Epsco Model BF-601 Signal Separator units, each of which contains 23 band-pass filters, are available for separating the composite sub-carrier signal prior to input to FM Converter.

Complete FM telemetering receiving stations are available with or without wow and flutter compensation and zero and 100 percent correction features. Also available is the Epsco Model VCO-718 All-Channel Voltage-Controlled Oscillator for FM Discriminator calibration . . . which occupies only 3½ inches of panel space including power supply.

In the West, contact:
Epsco Service Corporation of California
1722 Westwood Boulevard
Los Angeles 24, California

Epsco *incorporated*

588 COMMONWEALTH AVE., BOSTON 15, MASSACHUSETTS

MICRO SWITCH Precision

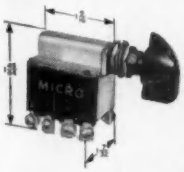
...FIRST IN PRECISION SWITCHING

If reliability, long life, ruggedness, compactness, sensitivity and accurate repeat point of operation are vital to you, then

Look to MICRO SWITCH for a solution of your Precision Switch problems

Here is a partial picture of some of the thousands of switch combinations available—news of a new MICRO SWITCH development—how and for what and why one manufacturer is using MICRO SWITCH Precision Switches—and a report on what MICRO SWITCH field application engineering can mean to alert design engineers

This MICRO SWITCH 3-Position Rotary Actuated Switch is compact and rugged



Ideal for airborne and industrial use, this switch is a four-pole double-throw switch with 12 terminals (catalog listing 4TR1). An eight-pole with 24 terminals is also available (catalog listing 8TR1) . . . Eliminates use of relays. Tested for impact, shock, acceleration and vibration. Careful inspection assures long life operation. Positively detented positions eliminate accidental operation. The solid silver contacts and silver-plated copper moving contact carrier provide maximum conductivity, minimum temperature rise.

(For more details ask for Data Sheet No. 112)

CHARACTERISTICS

Operating Torque (4TR1) . . 9 in. lbs. max.
Pretravel . . . . . 10° each direction
Operating Torque (8TR1) . . 4 in. lbs. min. to 6 in. lbs. max.

ELECTRICAL RATING 4TR1 & 8TR1

Continuous	Resistive Load		Lamp Load		Inductive Load	
	30 v dc	115 v ac	30 v dc	115 v ac	30 v dc	115 v ac
20	20	20	5	4	12	15



This Compact Limit Switch Is Widely Used by Industry

This is a double-pole two-circuit switch, completely sealed. Cover screws are held captive in cover when it is removed. The ½ n.p.t. internally tapped opening is in the bottom of the enclosure . . . Actuator can be positively locked in any position through 360° and can be operated in either direction. Actuator head is removable in field, can be rotated to any of four positions. This switch can be mounted either front or back side, .192-inch diameter holes extend through the enclosure, tapped from the back to a depth of 9/16-inch with ¼-20 nc thread. Mounting holes accept No. 10 screws. No. 8 terminal screws accommodate No. 14 stranded wire. Can be used single-pole double-throw.

(Ask for Catalog 101)

CHARACTERISTICS

Operating force—3 lbs. max. **Pretravel—20° max.**
Full overtravel force—6 lbs. max. **Diff. travel—12° max.**
Release force—½ lb. min. **Overtravel—30° min.**

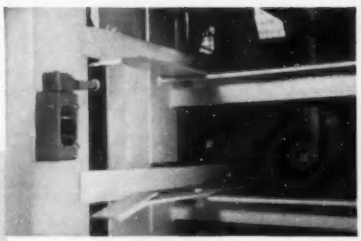
Rated: 10 amps. 120, 240, 480 v ac; ½ H.P. 120 v ac; 1 H.P. 240 v ac; .8 amp. 115 v dc; .4 amp. 230 v dc; 1 amp. 550 v dc. Pilot duty rating 600 v ac. max.

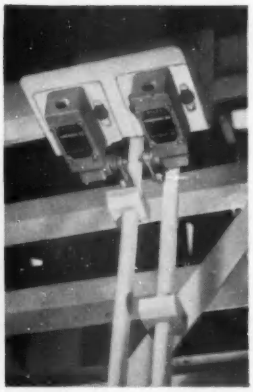
15 MICRO SWITCH Precision Limit Switches Assure ABSOLUTE DEPENDABILITY in Particle Board Loader and Unloader Unit*

Operates 20,000 cycles per day on a 24-hour basis

•

Prevents shut-down time at estimated cost of $50.00 to $100.00 per minute





Three of the many MICRO SWITCH Type "ML" 2-circuit switches index the cage stops of the upward and downward travel of the racks of the particle board loader and unloader unit.

Operating 20,000 cycles a day, these rugged MICRO SWITCH "ML" Limit Switches with their long life, accurate repeatability of point of operation, excellent seal, convenient mounting and one-way actuation features, provide dependability for the continuous high speed production of particle board.

Serving as indicators and timers in various automatic operations, these two-circuit switches control the up and down motion of the unit which loads and unloads the particle board to and from the hot plate press.

The manufacturer* of these custom-built units has standardized on MICRO SWITCH Precision Switches because of their longer life, accurate and dependable operation and excellent environmental seal. As many as 100 switches are used on some of these custom-built units.

(Ask for Catalog No. 83 "Industrial Enclosed Switches")

*Washington Iron Works, Seattle, Washington

Switches have uses unlimited



NEW!

A Subminiature Screwdriver Operated Switch— Saves Wiring and Panel Space

Designed to be used where there is limited access and where accidental operation must be prevented. Switch is operated by a 90° turn of a screwdriver and the slotted head gives visual indication of its position. The switch can be ordered with a number of variations of the subminiature basic switch. Contact arrangement is single-pole double-throw (maintained position).

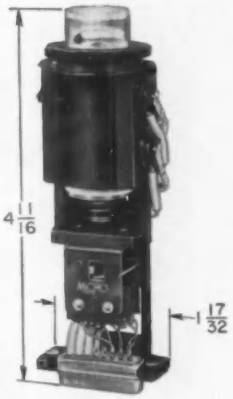
(To learn full details of this new switch, send for Data Sheet No. 115)

ELECTRICAL RATING

Listed by Underwriters' Laboratories at 5 amps. 125 or 250 v ac. The 30 v dc is: Inductive—3 amps. at sea level, 2.5 amps. at 50,000 ft., resistive—4 amps. at both sea level and 50,000 ft. Maximum inrush capacity—20 amps. ac and 24 amps. at 30 v dc.

MICRO SWITCH 3-Light Pushbutton Switch Reduces Panel Space 50%

This compact, double-throw double-pole switch with its prewired plug will light in three different colors. It was developed expressly for use in complex console panels. Because push button and switch are combined in one unit, it reduces panel space by 50%. The compact stem carries three separate lamps. The switch incorporates a special connector plug which permits quick and easy installation and replacement—no complicated wiring required. Designed for use where high reliability is a requirement; two SPDT precision subminiature basic switches with fine silver or gold contacts and special treated snap-acting springs are the switching elements. All materials are corrosion resistant.

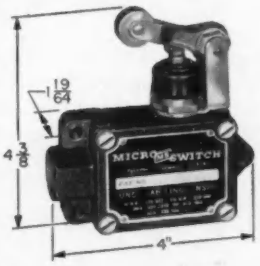


(Data Sheet No. 110 will give you more details. Send for it!)

ELECTRICAL RATINGS

Rated for .1 amp. inductive at 28 or 48 v dc and 1 amp. inductive at 115 v ac.

For Tough Service in Industrial Applications— The "BAF1" High Capacity Series



Especially designed for rough, general service in industrial applications, these MICRO SWITCH Precision Switches are protected from the effects of dirt, dust and occasional liquid splash by an elastomer boot on the plunger and an O-ring gasket under the cover plate . . . This series is really rugged, the three mounting holes in the heavy mounting flange accommodate ¼ in. bolts. These switches have a capacity to make and break steady state currents of 20 amperes and will handle inrush currents as high as 75 amperes. If your service requirements are rugged, this rugged switch will handle them.

(You can learn all about this series, if you send for Catalog No. 83)

CHARACTERISTICS

Operating force	2 lbs.
Release force	1/2 lb. min.
Pretravel	7/32 in. max.
Overtravel	1/4 in. min.
Differential Travel	.015 in. max.

Service Pays Off Again; for Orin McIntyre

"We don't sell switches, we *give* service. Give them the right switch for the job and the switches sell themselves."



That's the sales approach of Orin Mac McIntyre, MICRO SWITCH salesman. And Mac's approach recently paid off.

Mac offered his talents to a prospective customer's engineers, hoping to assist them with their switching problems.

Mac kept at it and finally found the "in." The prospect needed heavy-duty limit switches with extremely light operating force and soft-roller actuators to prevent breakage of his product. Mac checked the home office, found the perfect solution, and had two samples in the hands of the prospect—pronto.

This prospect's engineers found these switches ideal for their needs, and issued an order.

This fast and efficient service made an impression. Soon Mac was called in on another switching problem which resulted in a second order.

Through Mac's efforts, MICRO SWITCH has gained the added respect of this company.

MICRO SWITCH

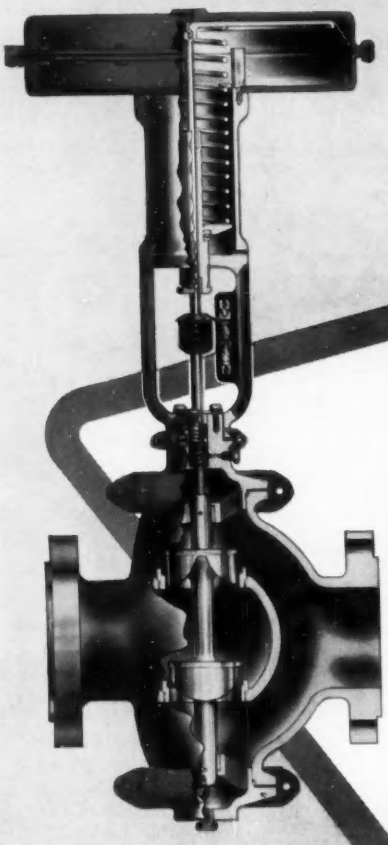
A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

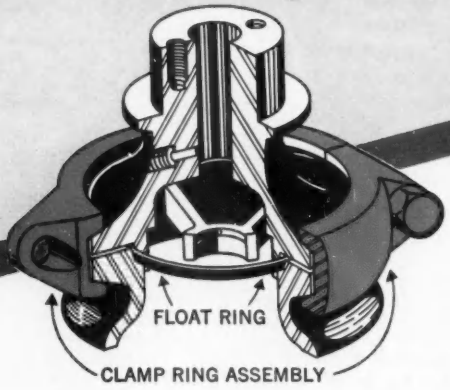
In Canada, Leaside, Toronto 17, Ontario • **FREEPORT, ILLINOIS**

New Clamp Ring···Float Ring Seal*

On BS&B's *Super* 70 series

Diaphragm Control Valves





...Makes Other Valve Closures Obsolete!

* Patented

The BS&B Super "70" Series Diaphragm Control Valves offer a thoroughly proven concept of pressure sealing, known as the clamp ring — float ring seal, for top and bottom closures.

Tightening of the heavy forged steel clamp ring seals the nickel plated, soft steel float ring into a precision machined, wedge-shaped groove formed by the valve body and the closure plate. Float rings are available in other materials compatible with alloy or stainless steel valve bodies.

Under pressure, the float ring is wedged tighter into its annular groove — thus increasing the sealing force. The higher the internal pressure, the tighter the seal!

This actuation under pressure also creates automatic compensation for thermal expansion under fluctuating temperatures. The seal is maintained under vacuum because initial tightening of clamp ring provides sufficient sealing force to hold a vacuum differential of up to 15 psi. Valves may be disassembled as often as required without damage to the clamp ring — float ring seal.

While a new BS&B exclusive feature in the diaphragm valve field, the float ring seal concept has also been most successfully used over the past several years by other leading manufacturers of high pressure equipment.

Why Clamp Rings Are Used On Super "70" Series Valves

The equivalent bolting area of the clamp rings used on Super "70" Series Valves is greater than that of a similarly rated ASA flange — yet is lighter in weight and more trim in appearance. Clamp rings make the valve easier to disassemble for servicing and cleaning because only two bolts must be removed, and permit the valve yoke to be oriented to any convenient position.

For more information on the all-new BS&B Super "70" Series Diaphragm Control Valves, ask your BS&B Sales Engineer — or write for Catalog 70-11.

EFFICIENCY OVER 60 YEARS BS&B RELIABILITY
ANOTHER EXAMPLE OF PRODUCT LEADERSHIP

BLACK, SIVALLS & BRYSON, INC.

Controls Division, Dept. 4-ES3

7500 East 12th Street Kansas City 26, Missouri

DON EARLY **knows his process**

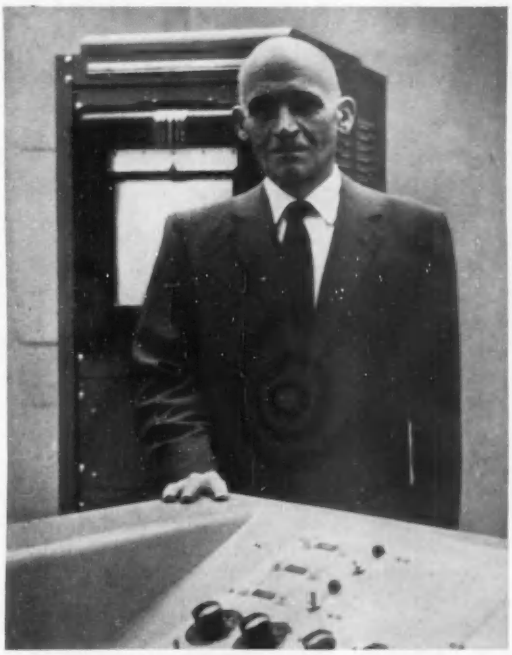
When he first began work on a design for an incremental cost computer to control electric power generation*, Don Early was rusty in his mathematics, had never seen the inside of a computer textbook, and had no formal training in control engineering. And just to make things more interesting, he was not playing around with peanuts: his employer, destined to become his guinea pig, was the Southern Co. Power Pool, a four-company system covering 115,000 square miles and handling a peak power demand of nearly 3¼ million kw.

But there was something in Early's favor that no amount of computer training could replace: a thorough and profound understanding of his process. The E. D. Early who was manager of the Southern Pool might not have been among the top ten computer specialists in the country, but in the field of integrated power-system operations, he was a recognized authority. This knowledge not only indicated the need for an automatic loading system for the power stations which he supervised, but showed him how to go about building one. The result was a "hobby" that has occupied him ever since.

Although he had maintained an interest in mathematics since his graduation from MIT in 1925 with an MS in electrical engineering, Early had to do some fancy brushing up as well as no small amount of original work before starting on the actual design of his analog computer. One of his contributions: a method of calculating the *B* coefficients of the incremental transmission loss equations from the results of network analyzer studies. All this without even knowing, when he started, the meaning of tensor analysis!

Chattanooga-born Don Early came to MIT from the U.S. Naval Academy at Annapolis. After his graduation he returned to Chattanooga to work in the Production & Transmission Dept. of the Tennessee Electric Power Co. While he was there TEPCO became part of the southeast power system, a development that set him to studying integrated power operation. When TEPCO was bought by TVA in 1939, he went to Birmingham with the Commonwealth & Southern of New York as an engineer in the power pool office. The Southern Co. succeeded C&S in 1949, and shortly after that Early was made manager of the power pool office of Southern Services, Inc.

After selling his company on a 24-hour-a-day coordinating office, Early began a study of the analysis of power systems and found that economic operation required consideration of transmission losses as well as generating costs. One, he saw, was barely of any value without the other if economy was the object, for the first accounted for the important factor of variable incremental cost, the second for the long transmission distances often involved in power distribution. He then undertook the design of a computer to calculate both incremental generating costs and incremental transmission losses to obtain incremental cost of power delivered.



Don is flanked by evidence of his achievement: the console of the Early Bird, and a temporary recorder checking his new automatic station loading system.

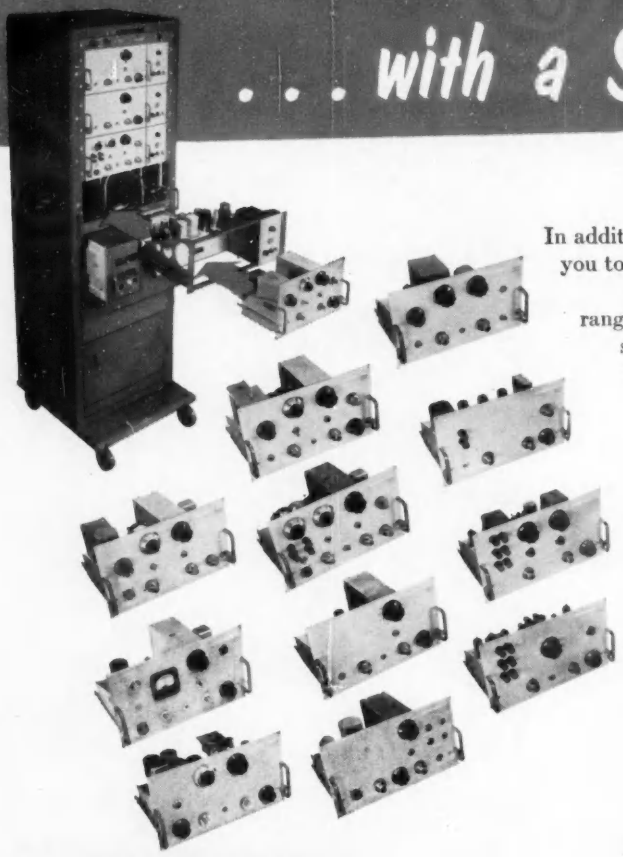
When in 1953 Leeds & Northrup offered to build the computer on an experimental basis, it had nothing to go on but a design, for Early had skirted breadboarding. But he had worked the circuits out on paper and verified them mathematically, and when they were finally built, L&N found them quite practical and satisfactory. The only thing left to do was to iron out a few details.

Once he recognized the need, Don Early's lack of "systems" training didn't deter him. He dug in to learn the mathematics that he had to know. He already had the confidence of familiarity—he knew his process. The result: the Early Bird—one of world's first economically optimizing incremental control systems.

* CONTROL ENGINEERING, Dec. 1956, page 77.

Get what you really need in oscillographic recording

. . . with a SANBORN "150"



The specific advantages common to all Sanborn "150" systems are shown at the right. In addition, the fundamental design of the Sanborn "150" allows you to purchase and set up *only* what you need for your direct-writing oscillographic recording needs (in the 0–100 cycle range). There are no standard "150" recording systems. Each system in use today comprises (1) a basic assembly in the number of channels the user needs, and (2) a *choice* of interchangeable preamplifiers according to the nature of the immediate or anticipated measurements desired to be recorded by the user.

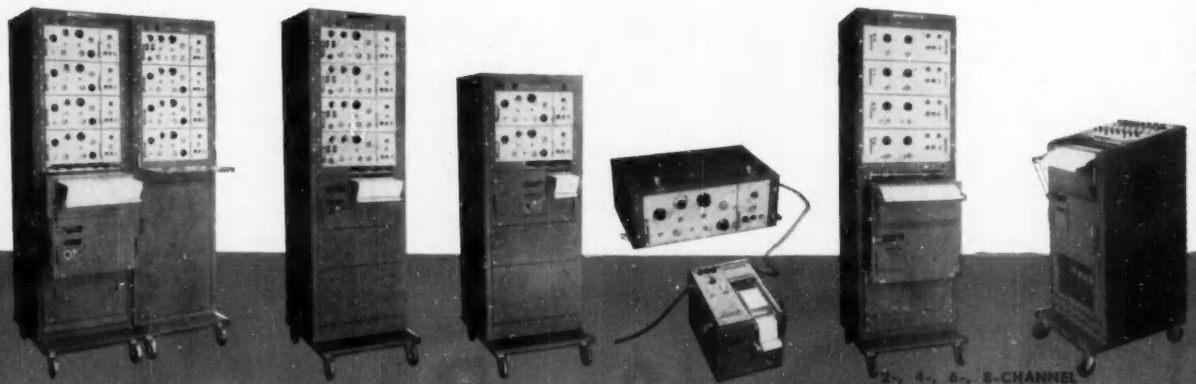
For example, the purchaser first selects either a 1, 2, 4, 6 or 8 channel Basic Assembly, each of which comprises a complete Recording Assembly in a metal mobile cabinet (or portable cases if 1-channel), a Paper Take-up Unit, and for each channel a Driver Amplifier with frame and Power Supply including Control Panel. Each Driver Amplifier is designed to receive, by simple plug-in connections, any of the eleven currently available Preamplifiers listed below.

To complete his "150" Recording System, the user then purchases the interchangeable Preamplifiers designed specifically for his recording requirements. Available "150" Preamplifiers cover a wide range of uses and include: AC-DC Carrier, Servo Monitor, Low Level DC Coupling, Log Audio, Chopper Stabilized DC, AC Wattmeter, RMS Volt/Ammeter, 400 cycle Frequency Deviation, and Frequency Meter. For those who wish to build special Preamplifier circuits to their own design, a Blank Preamplifier Chassis is available which may be used along with any of the standard Preamplifiers mentioned above.

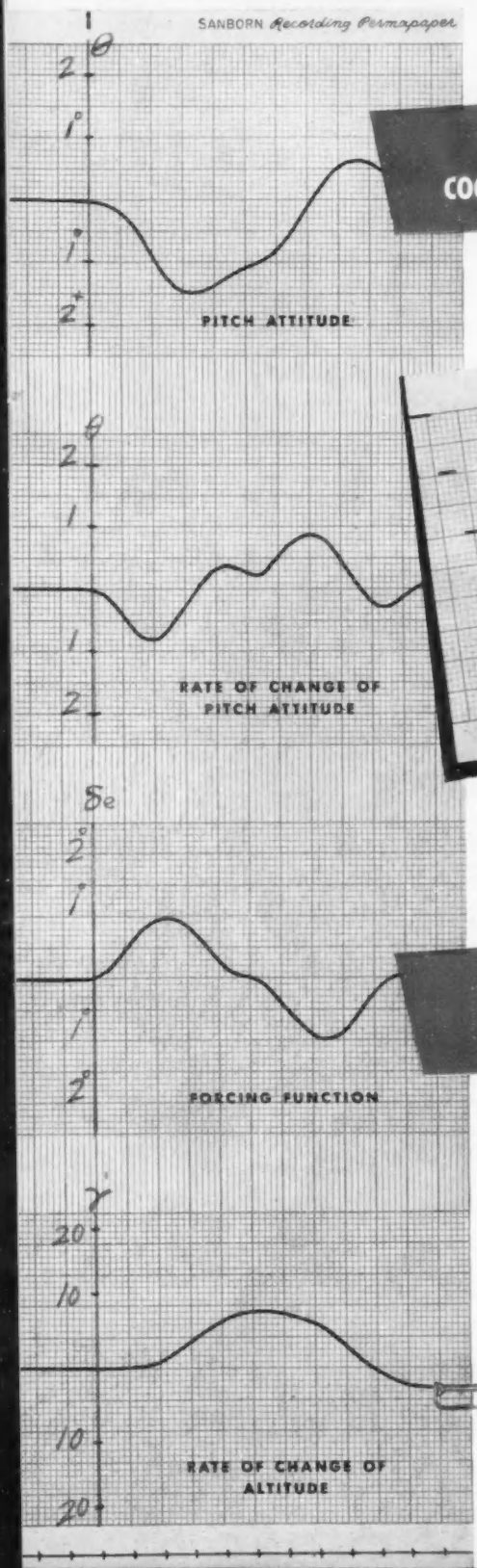
AT I. R. E. SHOW

Booths 3601 and 3603

Dynamic display of differential transformers and velocity transducers, along with complete display and demonstration of Sanborn recording systems with interchangeable preamplifiers.

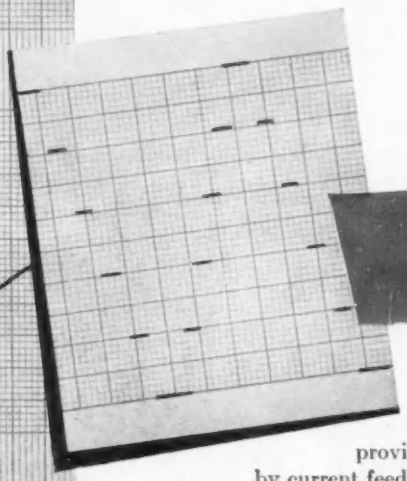


8-, 6-CHANNEL | 4-CHANNEL | 2-CHANNEL | 1-CHANNEL | 2-, 4-, 6-, 8-CHANNEL FOR ANALOG COMPUTER READOUT SYSTEMS



TRUE RECTANGULAR COORDINATE RECORDING . . .

Sanborn "150" recordings save you valuable analysis time, and minimize the possibility of errors in interpretation, by presenting data in *true* rectangular coordinate form. Without waveform curvature, "negative" time lines, etc., traces in multi-channel records can be easily and accurately correlated, during as well as after recording.

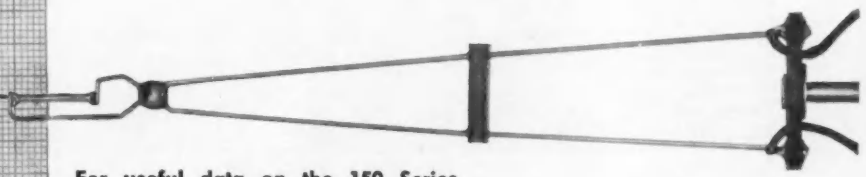


1% LINEARITY . . .

To meet your requirements for *accurate* recordings, Sanborn 150 systems provide over-all linearity of 1%. This is accomplished by current feedback driver amplifiers (one in *each* channel), and galvanometers of new design, featuring high torque (10 ma develops 200,000 dyne cm) and shorted coil frames. Maximum error over middle 4 cm of chart is 0.25 mm; over entire 5 cm chart width, 0.5 mm. Hysteresis effects have also been reduced in the recording galvanometer assembly, to further improve over-all recording accuracy.

CLEAR, SHARP, INKLESS RECORDING . . .

A third basic feature of all "150" recordings is that they are *inkless*, produced by hot ribbon stylus on heat-sensitive Sanborn Permapaper. The stylus removes the white opaque surface of the chart leaving the black undercoating to show through. Permanent and smudge-proof, the traces are characterized by sharp, blot-free peaks and notches.



For useful data on the 150 Series systems and equipment to meet *your* needs, write to Sanborn outlining your application requirements.

SANBORN COMPANY

WALTHAM 54, MASSACHUSETTS

INDUSTRIAL DIVISION

Kepco

VOLTAGE REGULATED POWER SUPPLIES

for Transistors • Strain Gages
Relays • Filament Power

MODEL	Volts	Current	Regulation Line 105-125	Regulation Load 0-Max.	Ripple	Recovery Time*	Stability For 8 Hours	Output Impedance DC-20 ~	Output Impedance 20 ~ —100 KC	Dimensions W	Dimensions H	Dimensions D	Price
2600	0-60	0-2 Amp.	5 Mv.	5 Mv.	1 Mv.	50 μ sec.	10 Mv.	0.002 Ω	0.0005Ω	19″	10½″	17″	$690
2650	0-60	0-5 Amp.	5 Mv.	5 Mv.	1 Mv.	50 μ sec.	10 Mv.	0.001 Ω	0.0002Ω	22½″	28″	19″	$1190

Good stability
Fast recovery time
Low output impedance
Excellent regulation
Low ripple

POWER REQUIREMENTS: 105-125 volts, 60 cycles.
FUSE PROTECTION: Input and output fuses on front panel. Time delay relay is included to prevent unregulated voltage from appearing at the output terminations.
OUTPUT TERMINATIONS: DC terminals are clearly marked on the front panel. Either positive or negative terminal of the supply may be grounded. DC terminals are isolated from the chassis. A binding post is available for connecting to the chassis. All terminals are also brought out at the rear of the unit. Two terminals are mounted at the rear of the chassis to provide for picking up the error signal directly at the load. This connection compensates for the voltage drop in the wires (and ammeter) connecting the power supply to the load.
METERS: Ammeter: 0-2 amperes, 4″ rectangular for Model 2600
0-5 amperes, 4″ rectangular for Model 2650
Voltmeter: 0-60 volts. 4″ rectangular
CONTROLS: Power on-off switch, DC on-off switch, remote error signal on-off switch, coarse and fine voltage controls. The coarse voltage control is a ten turn potentiometer which varies the voltage from 0-60 volts. The fine voltage control is a ten turn potentiometer which varies the voltage 1 volt. The voltage divider network allows a 61 volt variation in output voltage.
*Recovery time is less than 50 microseconds. The excursion in the output voltage during the recovery period is less than 50 millivolts for line fluctuations from 105-125 volts or load variations from 0-to maximum current.

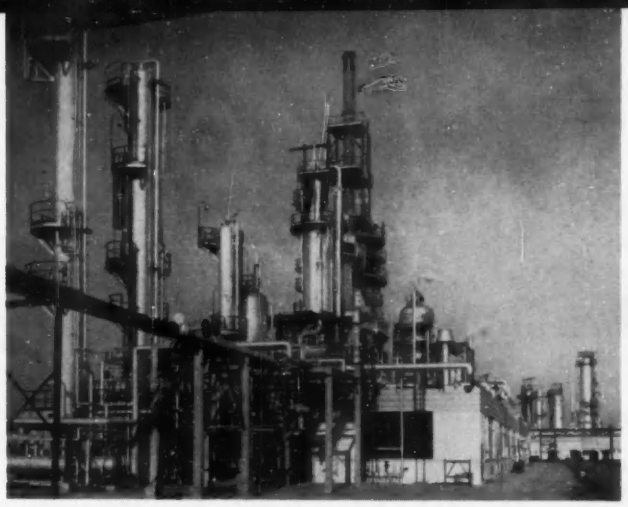


FOR COMPLETE LINE
WRITE FOR CAT. B-568

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WHAT'S NEW

Where will the next significant step towards computer process control take place? Odds are that it will be down in Belot, Cuba, where a new Esso cat-cracker—similar to the Imperial Oil unit pictured—will soon go on-stream with a unique addition to its automatic control equipment: an automatic data-logger-computer.

Will the Logger-Computer Optimize Refining?

Sometime toward the end of this year (target date, November) Esso's refinery now being constructed at Belot, Cuba, will go on-stream with an automatic data logger-computer. The data logger, or log sheet printer, is similar to others in oil refinery use, but the computer is of significance to control engineers as a step along the road to computer-control.

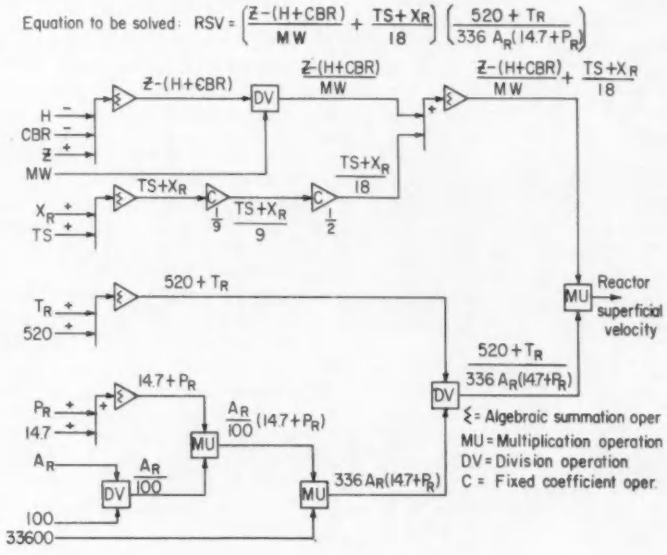
Heretofore, data loggers have included some computing, such as square-rooting, linearizing, and totalizing. But each item recorded on the loggers generally came from an individual measurement. Esso's concept of joining elaborate computing functions (such as those that could take four, five, or more measurements and from them compute one process variable of greater significance) to the data logger stems from the incentive of optimized process operation. A total of 11 computations is planned, yielding eleven "operating guides", as these computed process variables have been termed. The operator will use them to run the unit more efficiently and to prevent major plant upsets.

Project status

Right now construction of the refining unit, a fluid catalytic cracker, is being supervised by Arthur G. McKee & Co. for Esso Standard Oil, S. A. Fischer & Porter, working from specifications and computing equations prepared by Esso Research & Engineering's engineering divisions, is building the logger-computer. Essentially, it will measure 101 process variables in analog form and convert these to digital readouts. Some of the measurements, stored in analog form, will be fed into an automatically programmed general-purpose analog computer. Eleven computed results will then be converted to digits and printed out as true values. Sequential solution of the governing equations in proper order will minimize equipment needed. Fischer & Porter's Bob Stern and Chuck Taylor reveal the design of their equipment on page 26.

What next?

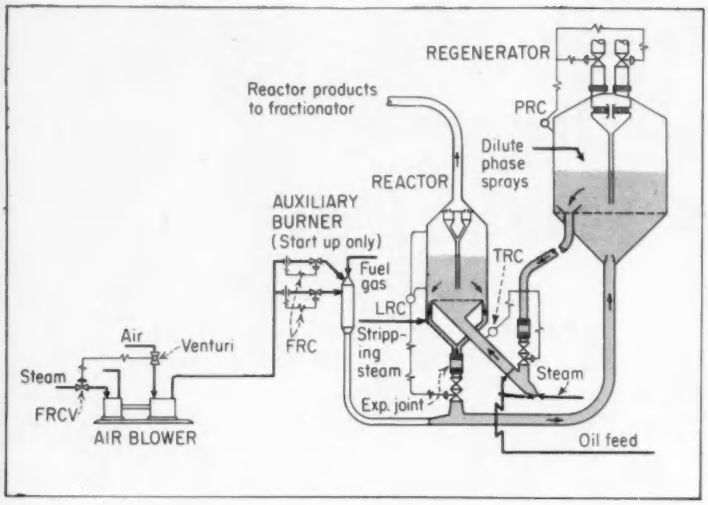
The logger-computer installation at Belot is exploratory. Few process unit loggers can of themselves be justified today, as is obvious if one notes the few process units incorporating them in the unit design. In conjunction with the computer, however, other possibilities open up. The $50,000 price for the dual-function equipment ($60,000 installed) will be small indeed if the final results do actually help the operator optimize operations with the 24,000-bbl-per-day feed rate and provide enough correlation information for eventual closed-loop automatic process optimizing.



HOW THE COMPUTER WILL SOLVE FOR OPERATING GUIDES:

Computation of the reactor's superficial velocity represents the type of solution the logger-computer will perform. The block diagram shows how the computation will be carried out using standard computing modules. This is the last in a series of 11 computations. Thus, some of the inputs, such as Z, H, and CBR, are available as subroutine stored values from previous calculations. Other inputs, such as P_R and T_R, come directly as analog values of process variables. Inputs such as MW and X_R, are manually preset. The resulting computed value, RSV, is converted from analog to digital form and printed on the log sheet periodically, or on demand.

FOR REPORTS FROM BOTH USER AND MAKER TURN THE PAGE . . . ➔



Belot Logger-Computer

The User Reports

Diagrammed on the left is the fluid catalytic cracking process that will be brought under logger-computer supervision. In his special contribution below, Harry F. Moore of Esso describes how 101 variables will be reduced to 11 useful operating guides . . . and explains why this can be a big step towards process optimization.

HARRY F. MOORE
Esso Research & Engineering Co.

At the present time automatic data loggers installed in refineries record for the operators' use the values of important process variables that can be measured–chiefly temperatures, pressures and flows. There are other important variables involved in refinery processing that are not so recorded, simply because they are not now measurable at the unit. Some can be measured by taking samples to the laboratory, such as analysis of streams, and product specification such as motor gasoline octane number. Others can be computed by means of formula, slide rule, and engineers. An example of such computable information, now being automatically computed in the utility industry, is furnace efficiency. Such computable items have been called "operating guides". Frequently such operating guides are of more significance to a process unit operator then the measurable variables, but they are not available to him unless a technical man is present. Thus, a unit can stray from optimum operation or even get into difficulty.

A logical approach to eliminating the deficiency was to investigate the possibility of tying a computer to an automatic data logger so that individual measurements of process variables would be gathered, stored, and logged, and the computer would solve the pertinent equations from the stored measurements and log the operating guides along with the original data.

Esso's new refinery under construction at Belot, Cuba offers an opportunity to try out this logger-computer idea. The fluid process catalytic cracker and associated fractionator are similar to installations at other refineries. The process is not new, but there is much to learn about it and its optimization.

The fluid catalytic cracking process shown above converts a feed stream, usually a heavy greenish-black gas oil, into about 50 percent gasoline plus other materials such as domestic heating oil. Efficient cracking operation is primarily a matter of balancing quantity and quality of the gasoline product. The oil feed stream enters the reactor input line where it mixes with the 1,100-deg-F catalyst and then flows into the reactor chamber as a vapor. Inside the reactor the vapor's molecular structure changes: volatile hydrocarbons leave the reactor overhead as a hot vapor and feed into a fractionator for further separation; and carbon from the feed oil is deposited on the catalyst. During the operation the carboned or "spent" catalyst must be withdrawn at the same rate the new catalyst enters with the feed stream. The spent catalyst leaving the bottom of the reactor is picked up by compressed air and forced into a regenerator where oxygen in the air burns off the carbon. The regenerated catalyst then returns to the reactor with the new feed oil entering the process. The 11 selected operating guides for this cracking process are:

1. Carbon burning rate–indicates the amount of carbon burned in the regenerator per hour. Measurement of CO_2, CO and O_2 all of which are directly measurable, are put into a material balance equation to yield the carbon burning rate.

2. Catalyst circulation rate–involves a heat balance equation to find out how fast the catalyst circulates through the regenerator and reactor. Here measurements of four temperatures, and flue gas, air, CO and CO_2 rates enter into the computation.

3. Catalyst flow to oil flow ratio–is obtained by dividing the catalyst circulation rate obtained in 2 by the net oil flow in the system.

4. Ratio of feed to reactor catalyst holdup–is a measure of how long the oil remains in contact with the catalyst. It is given in lb of feed per hr per lb of catalyst present.

5. 430 deg F vapor temperature conversion-corrected–tells how much feed stock is being turned into gasoline, and thus is an indication of process efficiency.

6. Percent weight of hydrogen in coke–measures how much oil is lost with coke into the regenerator and thus indicates efficiency of stripping operation. This weight must be kept to a minimum to prevent excessive loss of oil and compressed air.

7. Percent weight of carbon make on total feed–also indicates the effectiveness of cracking. Keeping this value to a minimum usually means least fixed gases, and most gasoline.

8. Heat duty of top pumparound system–a stream on the fractionator is removed from the top of the column, fed through a heat exchanger to remove heat, and returned. Heat duty measures heat removal.

9. Heat duty mid pumparound system–similar to 8, but measures heat removal from stream taken from middle of fractionator.

10. Regenerator superficial velocity –a rough measure of the velocity of gas through the regenerator. This measurement is important in connection with catalyst recovery.

11. Reactor superficial velocity–similar to 10.

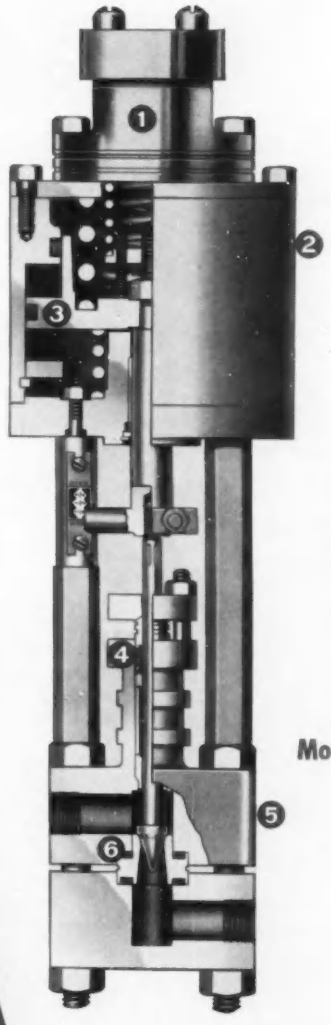
Range setting

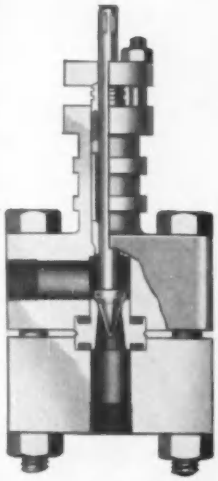


Split second action ...small flow control ...at 6,000 psi

New achievement by Annin in high pressure control and precise valve response for Research–Development–Process applications

Annin's new Model 9460, designed for working pressures to 6,000 psi, provides research, pilot plant and process control engineers with an extremely responsive small flow control valve suitable for low capacity systems. The operator will fully stroke in either direction in 0.75 seconds or less. New design features include: ❶ integral positioner, open-on-air-failure or close-on-air-failure action; ❷ Annin's 600 Series Domotor operator; ❸ differential area piston, eliminating need for loading regulator; ❹ universal stuffing box for −400°F to 750°F; ❺ offset globe or angle body design; ❻ valve plug stem and seat ring common to both globe and angle bodies. For reliable fluid control and flexibility of application Annin offers the *best source* for solving any small flow control problem.





Model 9461 *angle body*

Angle bodies are available with body sections rotatable in 90° increments for piping convenience.

YOURS FOR THE ASKING—
Complete information and specifications are contained in Bulletin No. 9400. Write for your copy today.



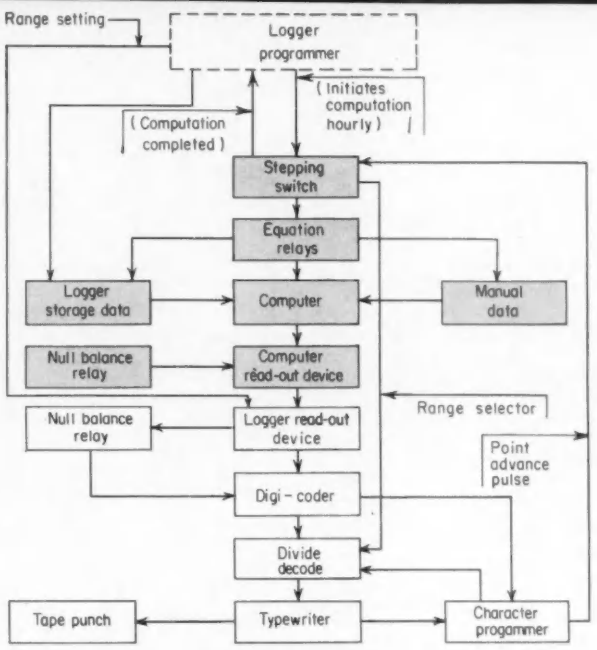
ANNIN *Control* **VALVES**

THE ANNIN COMPANY
DIVISION OF THE ANNIN CORPORATION
6570 Telegraph Road, Los Angeles 22, California

Belot Logger-Computer

The Maker Reports

In this contribution from the data handling system supplier. Bob Stern and Chuck Taylor of Fischer & Porter Co. explain how the logger and computer will be coordinated in Belot. They detail the problems of accuracy, the computing cycle, and some of the basic computing functions.



Coordination between logger and computer functions Fig. 1

R. K. STERN & C. H. TAYLOR
Fischer & Porter Co.

The computing portion of the comter-logger for Esso's Belot refinery is essentially an arrangement of standard computing functions programmed to solve the specific equations whose answers are the operating guides used in determining process efficiency. Logical design of this equipment adapts a general-purpose analog computer for special-purpose computing. This approach simplifies system design, component procurement and maintenance, and provides, simply by changing a program, the flexibility needed for exploring and learning about the process.

Process and installation needs

The computer portion of the equipment uses ac analog modules throughout. The ac signals come from oversize transformers giving 5-volt outputs, which eliminate frequent calibration and standardization procedures and thus assure continuous-duty operation with a minimum of routine preventative maintenance. Voltages greater than 5 volts can be obtained by connecting several transformer secondaries in series-aiding and picking off the desired value.

Installation of this equipment in a refinery calls for due regard to hazardous conditions. The three cabinets comprising the overall logger-computer will therefore be air-purged and will conform to Article 500 of the 1953 National Electrical Code, Class I, Group D, Div. 2.

All necessary linearization of thermocouple inputs, conversion of customer's 3-15-psi pneumatic signals to digital signals, and the extraction of square-root functions will be accomplished in the logger portion of the equipment. The accuracy for the logged process measurements are:

- ▶ temperatures—plus or minus 0.25 percent
- ▶ pressures—plus or minus 0.5 percent
- ▶ compensated flows—plus or minus 1.0 percent
- ▶ integrated and averaged flows—
  - • plus or minus 1.5 percent from 10 to 25 percent of full-scale flow
  - • plus or minus 0.75 percent from 25 to 50 percent of full-scale flow
  - • plus or minus 0.5 percent from 50 to 100 percent of full-scale flow

The accuracy of computed operating guides are: plus or minus 2 percent.

How the computing section works

In Figure 1, a block diagram of the major components of the logger-computer, the shaded blocks refer to computer functions and programming. Inputs to the computer are:

- ▶ logged during a readout cycle and stored as a shaft position, or
- ▶ derived during the computation period and stored as a subroutine for later use, or
- ▶ fed into the computer manually

At the start of computation, stepping switch position 1 determines which equation relays should be operated to compute the first operating guide. Relay contacts connect and select input signals to computer building blocks and the resulting value is connected to the computer readout device. At the completion of the computing cycle a pulse advances the stepping switch to the next point, where contacts select the next set of equation relays.

Time-sharing the computer

The operating guides use a great number of the 101 measurements gathered by the logger. Each of the 11 operating guides is computed sequentially, that is, the computing equipment is time-shared to minimize the number of computer building blocks.

Figure 2 shows the time-flow diagram of the sequential solution of the equations. Here, Equation 1, yielding the carbon burning rate operating guide, is solved first. It is stored as a subroutine for subsequent use in solving Equations 6, 7, and 10, and also printed out on the operating guide log sheet. Equation 2 is solved next, using some of the other stored information obtained in solving Equation 1 plus other logged— and manual inputs. This procedure is followed, once an hour, until all 11 equations are solved and printed out on a log sheet.

Basic computing functions

The operating guide equation requiring the greatest number of different arithmetic operations determines the type and maximum number of basic computing modules in the computer. Then, because of the time-sharing design, these modules are used over and over to solve less complicated equations. The modules perform sim-



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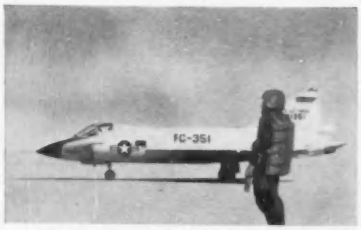
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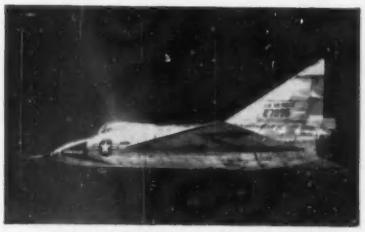
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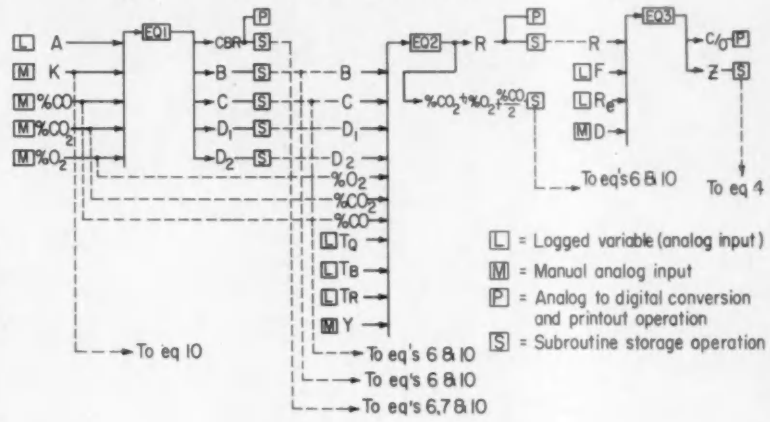
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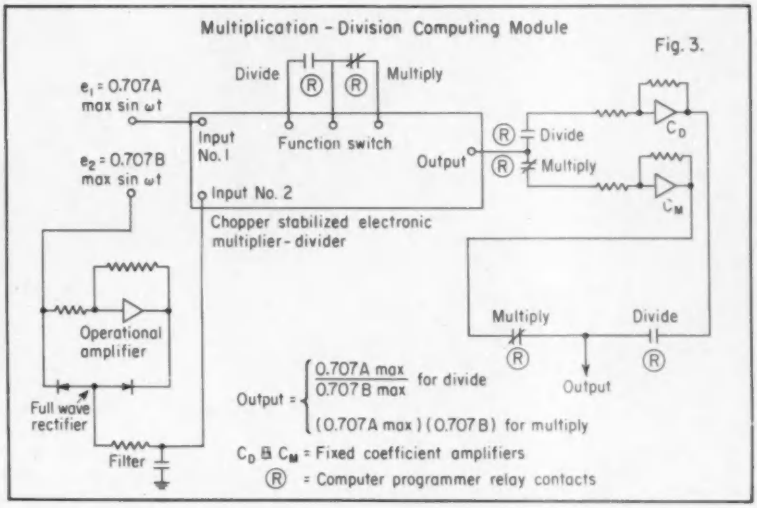
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WHAT'S NEW

Computer - logger solves 11 equations in time sequence Fig. 2





ple arithmetic operations and continue in sequence until the equation is solved. The basic arithmetic modules included in the computing portion of the logger-computer are:

- ▶ differential summation amplifiers (addition and subtraction)
- ▶ coefficient amplifiers (fixed constant)
- ▶ product amplifiers (multiplication and division)

Other modules in the computer are:

- ▶ memory systems (for storing data and subroutine computations)
- ▶ signal sources (ac voltages properly scaled for use in the equation)

Figure 3 shows the schematic for one of the basic computing functions, that of the multiplier-divider. Here, one of two input signals to be divided or multiplied is converted by a full-wave rectifier into a dc signal, which is then modulated by the second ac signal. This avoids the sine-squared voltage that would otherwise arise in taking the product or ratio of two ac signals. Auxiliary operational amplifiers C_D and C_M give the proper output voltage relationship. This circuit, chopper-stabilized to minimize dc drift, provides multiplication or division with unity gain.

Whether the module multiplies or divides depends on equation requirements, and thus equation relays selected during the program. The programmer first decides whether multiplication or division must be performed and selects this module. Then closing and opening of appropriate relays contacts sets up the module for the specific arithmetic operation.



RAMBLINGS ON INSTRUMENTATION

Systems, schmystems . . .



Being anything but complimentary about "The systems approach" is like campaigning for SIN these days. Thus, we were a bit taken aback recently when an instrument manufacturer friend came forth with this blast:

"Systems, schmystems . . . to engineer an integrated system of instruments and controls for a process where specs are fixed (not to mention the new "don't-raise-that-bridge-boys; lower-the-river" approach of engineering the total process system) requires lots of scarce, talented engineers. Our margin on our products in the resultant system is not adequate to cover system engineering costs, so we must add a charge. This charge is the first thing that's chopped out of the total price in competitive bidding. Ergo! There's a direct correlation between systems jobs and low profitability in our shop. In effect, we're a consulting engineer-manufacturer being paid only for manufacturing.

"Also," he continued, "there's the ethical question of whether one can be a good consulting engineer if he manufactures components which might be included in systems he engineers. Should we abandon manufacturing and become consulting engineers? Can only big manufacturers make money at systems engineering? How can you afford a team of engineers that knows a lot about the entire process as well as control technology?"

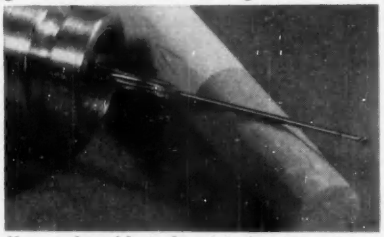
Retreating behind a screen of glittering generalities, we terminated this disturbing conversation. But we're still wondering if some thorny questions don't lurk behind the aura of glamour surrounding "the systems approach." Like "Who's going to do what and how does he get paid?"

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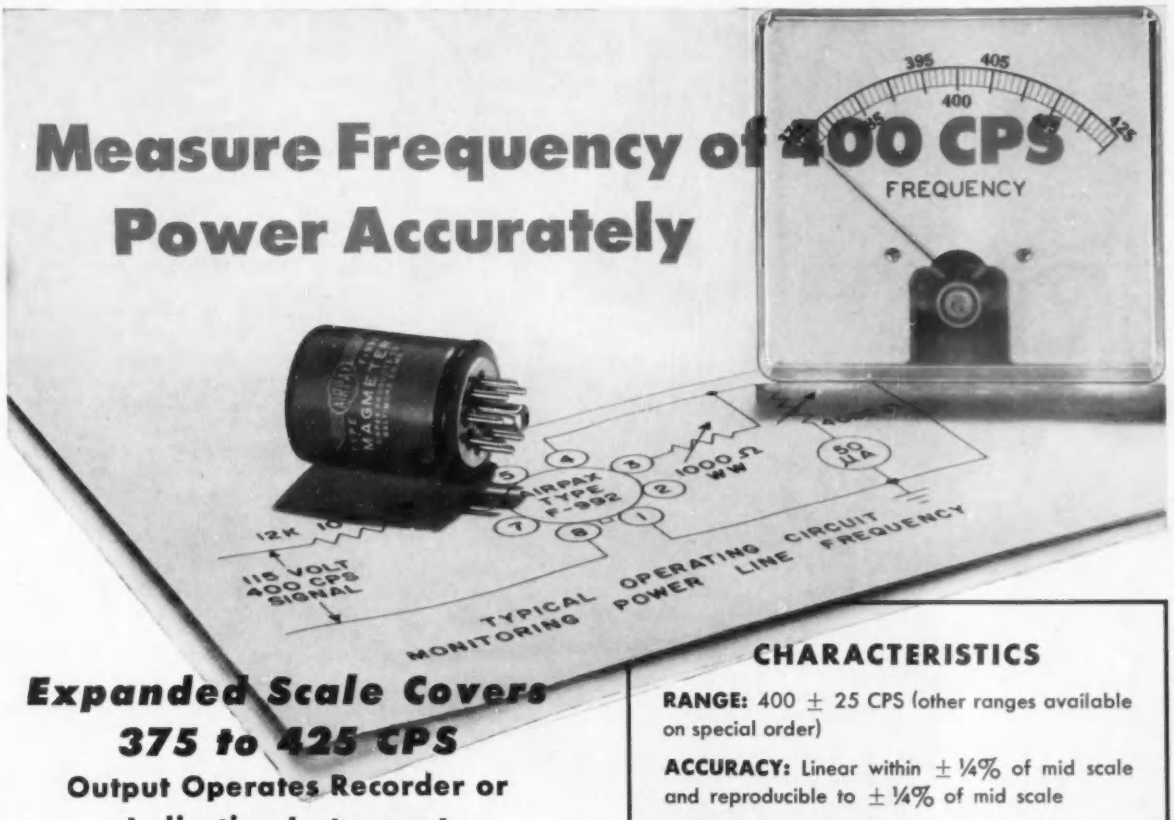
At the AIEE's recent Winter General Meeting in New York, unexpected controversy fired a special panel session on "Education in Electronics". It was the topic put to the panel that drew the interest: "Technicians can be trained to work as Junior Engineers". Lloyd Slater, who attended the session for CtE, commented when he wearily returned to his desk, "Who would have thought that such an innocuous subject would breed so much heat?"

Things started off quietly enough when Thor Trolsen of GE related how technicians are indeed being used—in a planned program—as junior engineers in his company. GE selects grads from two-year technical institutes, he said, then trains them further and assigns them to such recognized engineering jobs as designing motors and controls and engaging in quality control work. "Technicians have made many contributions at GE," claimed Trolsen, "We prefer a good technician to a mediocre engineer any day."

But the fur started to fly when Eric Walker of Penn State took the podium. Educator Walker suggested that the topic be switched to "Can technicians be trained as junior engineers?" He then issued a firm "No!" Setting up a junior engineer category, said Walker, would be to deliberately create a status of second-class engineer. Could Junior go on to become a Senior? asked the panelist. "Absolutely no. He would be completely lacking in the broad, fundamental grounding that is needed for the qualified engineer." The plan at Penn State, said Walker, is to utilize the great pool of technically-inclined youngsters in the 100-120 IQ range (an IQ of over 120 he said, is necessary for a degree-bearing engineer) by offering a special, terminal two-year course leading to an "Engineering Associate" certificate. "Forty percent of our population are in the 100-120 IQ range—only ten percent qualifies above 120," stated Walker. "A program of this type should graduate at least two technicians to every engineer."

The next panel speaker, K. O. Werwath of the Milwaukee School of Engineering, diplomatically skirted the controversy by describing how his institute made a realistic survey of

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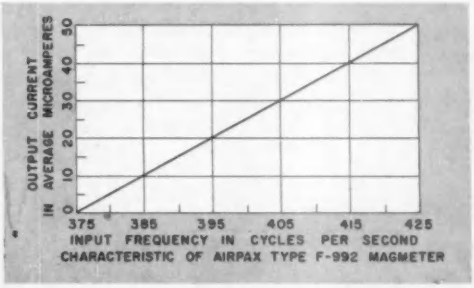
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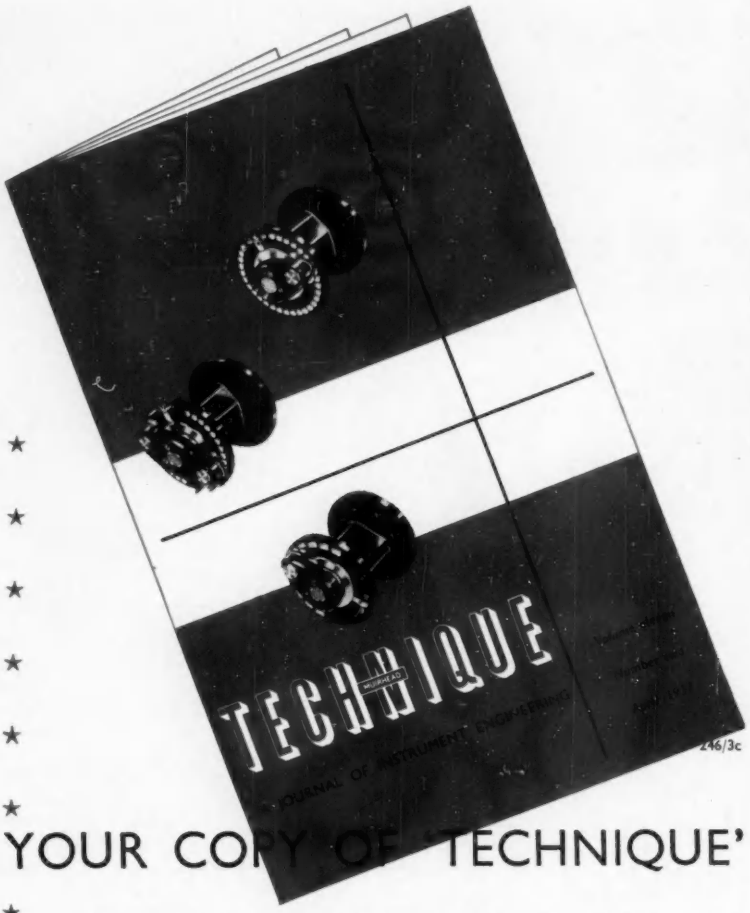
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WHAT'S NEW

the actual needs of technicians out in the field and then adopted its curriculum to these needs. "An engineering technician," he stressed, "must receive at least one-half of his training in the area in which he plans to specialize. The other half can be basics." Werwath said that there are only roughly 100 proper courses of this type in the U.S. and that, in recent years, there has been a decided movement of technicians from consumer service into industrial work. Werwath's talk, enriched by remarks from the floor by colleagues, was a dignified plea for a recognition of the status of the properly trained technician.

The last speaker of the panel, John Gore (Bethlehem Steel), talking for Newell Freeman of the New York State Board of Examiners of Professional Engineers, seemed to come, unknowingly, to the very heart of the controversy. Freeman's prepared paper was a quiet, thoughtful treatise on the problems of awarding a professional engineering certificate to nondegree men. Today, it said, it is becoming more and more difficult to justify experience as a substitute for formal university training in engineering. Further, wrote Freeman, only five percent of the technical institute graduates actually go on for the degree—a sure sign that the older, experienced nongraduate will have even less incentive and ability to get the degree (even if awarded a "professional" certificate based on experience). "There is no doubt," read Gore, "that a graduate degree will soon be a mandatory requirement for the professional engineering certificate."

Freeman's paper seemed to voice the real question: "Can you, **should** you give the technician a professional status by awarding him the word 'engineer' in his title?" The university educators and the practicing graduate engineers in the audience chorused, "No . . . the profession of engineering should be based on certain fundamental background training which equips a man for abstract and creative thinking." The company educators and personnel recruiters at the meeting chimed, "Yes . . . many technicians produce twice as much as an inept engineer, and the former deserve the dignity of the title as much as the latter." The technical institute educators stayed staunchly in the middle. "We just want our graduates treated with more recognition," they said.



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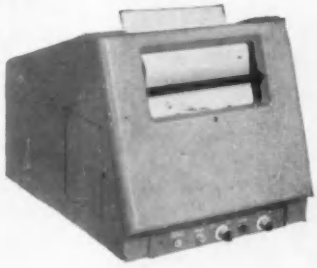
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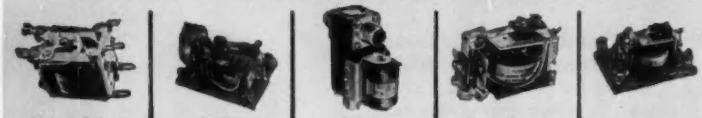


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WHAT'S NEW

Out of the lively question and comment session (many people seemed to rise to make statements rather than interrogate the panel) came agreement on this point: the engineering technician is indeed a needed and highly valuable commodity in our field and all efforts should be bent towards training this type of individual and somehow giving him the recognition he deserves.

L.E.S.

Chicago, April 9-10

Here is another one of those well-organized Armour Research Foundation two-day conferences on various phases of automatic control. The topic this time is "The Application of Electronics in Industry", and the co-organizer and co-sponsor of the affair is the Professional Group on Industrial Electronics of the IRE. Dr. Eugene Mittelman, chairman of the conference, advises that it will contain 11 papers in four sessions which will cover, 1) trends and basics, 2) process control electronics, 3) industrial machinery applications, and 4) nuclear electronics. The excellent speakers include Bill Wildhack of NBS on "Basic Instrumentation", Bert Ziebolz of Askania on "Communication Problems Between Instruments, Controls and Man", Waldo Kliever on "Direct Reading Digital Transducers", and Bill Geyger of NRL on "Applications of Magnetic Amplifiers to Industrial Instrumentation and Control".

IBM Paces R&D with a Handsome New Quarterly

IBM, which never goes into things in a small way (except when miniaturization is an important consideration), has brought out an intelligent and fine-looking quarterly magazine that ranks with the keystone items of many a publishing house. The first issue of "The IBM Journal of Research and Development" contains 100 pages of articles by IBM men associated with R&D, brief pieces called "Short Communications", abstracts, and a list of patents awarded to company people. Instead of an expensive format and loads of color photos, the staff, headed by C. R. MacKenzie, editor, makes its impression via technical reports on work done in the labs, and reviews, although it specifies that the latter must "contribute to a fuller understanding of the subject

COMPUTERS AND PROCESS CONTROL discussed by *Eric Weiss*

The application of digital computers to the direct control of processes brings up these two questions: (1) Can the control functions be properly formulated? (2) Can computers be made reliable enough?

Speed is no problem. Today's memory developments offer practically instantaneous access. A 50 kc or 100 kc serial computer is fast enough to satisfy most control operations. When this is not fast enough, the overall speed can easily be increased one or two orders of magnitude through the use of a parallel machine.

There is another way of speeding up a computer. Rather than build a general purpose machine which can compute any problem we like to code into it, special purpose computers can be designed and built for special jobs. The same proven elements would be utilized, but would be arranged in different arrays in order to come up faster and more directly with the desired solution. The resulting machine would most likely do the job faster without actually increasing the repetition rate.

The problem of reliability is not so easily disposed of. In the past, digital computers were primarily used as mathematical tools to compute lengthy mathematical problems or to process repetitive data. If a computer made an error once every billion operations (which at the rate of 100 kc would be every three hours), it was not too serious. The error was caught and the problem, at the worst, computed again.

The moment we start thinking about a computer in direct control applications, the problem becomes more critical. If the computer controls some sort of manufacturing or chemical process, a single error at the wrong time in the wrong spot can be catastrophic. Under such circumstances, an error probability of 1 in a billion cannot be tolerated. An almost errorless operation is required.

Most digital computers presently in production have a large number of hot vacuum tubes. These are the least reliable elements in a computer. Their filaments burn out; envelopes leak; or various fragile elements short.

During the last decade, a series of solid state elements has been developed which make it feasible to build a computer without vacuum tubes or moving elements. The diode, the transistor, the magnetic amplifier, the magnetic core and several other elements in this class can be expected, unless abused, to live and operate without mistakes practically indefinitely. Furthermore, they are considerably smaller, lighter, and less power consuming.

Consider a flip-flop, for example. Utilizing vacuum tubes, a flip-flop consists of at least a double triode, several crystal diodes, resistors, capacitors, plus the necessary hardware to mount the same. Such an assembly normally occupied the same space as a king-size package of cigarettes, and the required accessory equipment, such as power supply or air conditioning, occupied a similar space. In contrast, a transistor flip-flop could be packaged in a volume of the size of a peanut shell with the corresponding power supply even less. The power consumption is so minute that the unit can be potted and it is quite likely in the near future a whole computer could be potted.



Eric Weiss, nationally-recognized authority on computer philosophy and design, discusses the use of digital computers in process control.

The major obstacle to the use of computers in control applications is the lack of understanding of the processes which are to be controlled. A scientist can play with a general purpose computer in a control system. He can code it by trial and error. Once the formulae have been determined, a special purpose computer that would be smaller, faster, and more efficient, can be built to control the process.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

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or give a critical evaluation based on previously published matter". Fields to be represented in the new book include solid-state physics, chemistry, metallurgy, information theory, and electronics. A year's subscription to four issues (January, April, July, and October) sells for $3.50.

IN THE BUSINESS LOOP

SAMA's View of Year Ahead Clinches Bright Prediction

The picture of the control instrument market painted by McGraw-Hill's Dept. of Economics in its year-end report (CtE, Feb. '57, p. 37) has received bull's-eye confirmation by the Scientific Apparatus Makers Association. The correlation between the two reports is so close, in fact, that there seems to be no harm in saying that the prospects for 1957 have changed from simply pleasing to conditions calling for all-out jubilance.

The 15-percent increase in sales in 1956, which was reported by McGraw-Hill, for instance, fits like a glove into the more flexible, yet no less accurate 10-40-percent given by SAMA. So does McGraw-Hill's estimate of a 25-percent increase in sales in 1957, for, says SAMA, its own figure for 1956 is just part of a pattern of continuing growth—a growth which will see the 10-40-percent exceeded as this year matures.

The major reason for the continuing success of instrument makers, SAMA says, is the enthusiasm for research and development in the field they serve. It is this, "coupled with 'wise money's' ever-increasing investment" in R&D, which is largely responsible for an outlook head and shoulders over 1955, although in that year instrument makers made gains ranging from 5 to 15 percent above the year before.

Research and development by both large and small businesses, said SAMA's Executive Vice-president Kenneth Anderson, is becoming the very life-blood of industrial existence. He estimated that American industry will spend some $56.5 billion on these activities in the next ten years.

Decker Ionization Transducer Workhorse of Aerobee Rocket

Two things, among others, were unique about the flight of a Navy Aerobee-Hi rocket at Fort Churchill, Can., recently. One was that the

Another TI FIRST

true rectilinear side-by-side recording of two variables correlated to a common time base!



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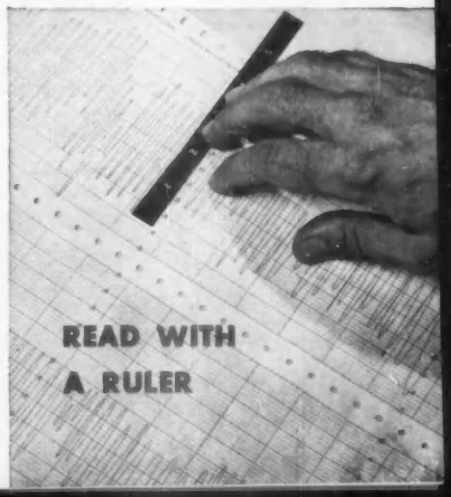
Now, work-saving rectilinear recording is made possible in hundreds of new industrial, laboratory, and mobile applications by the *DUAL recti/riter*. *One* compact instrument containing two independent galvanometers, inking systems, and "recti/rite" linkages—with a single chart drive—enables you to record two variables simultaneously and visually correlate events to an accurate common time base. No synchronizing of separate drive systems . . . only one chart roll to handle . . . interpret data at a glance on the *DUAL recti/riter*.

Record such variables as voltage and current, wind direction and velocity, temperature and pressure, torque and speed, input and output . . . these are just a few practical applications for the *DUAL recti/riter*. You will think of many more that fit your specific needs.

Both DUAL and SINGLE recti/riters have these outstanding features:

- Easy interpretation — read data directly with a simple ruler.
- Frontal access for all controls and routine operations.
- Accuracy of ±1% over full 4½-inch scale; sensitivity of 0.45 inch/100 microamperes; pen speed ¼-second/full scale deflection.
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- Non-corrosive metal alloy pen writes fine line with dependable non-smearing ink flow.
- Use ac drive; 6, 12 or 28-volt dc drive; spring drive; or external drive.
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For more complete information, write for respective bulletins— Dual recti/riter BR-502, and Single recti/riter BR-501.



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Synchronous and Induction Capacitor Type Motor



R-25 MOTOR

Approximately 2½" in diameter, the R-25 is available in either induction or synchronous construction with reversible rotation.

Typical applications are in recording instruments, dictating and adding machines. Available with gear case speeds from ½ to 3600 RPM, torque ratings up to 75 oz. inches or higher, and single, 2 or 3 phase.

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☐ Please have representative call on ..... (date)

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Company.....

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City.....Zone....State.....

heart of the rocket's pressure-measuring system was the T-42 ionization transducer developed by Decker Aviation Corp., the second that the transducer and all other components of the measuring system were completely contained within the pitot static tube. The T-42, a rugged piece of hardware, functioned perfectly despite heat and vibration, giving for the first time continuous and accurate measurements (0.005 psia generated an output of more than 1 volt) of ram and atmospheric pressures 125 miles above the earth. When it came out in the fall of 1954, the transducer was hailed for its ability to replace an impedance bridge, a phase-sensitive rectifier, and a voltage amplifier. One of its first applications was a differential pressure gage, which was so sensitive that a 5-volt signal output was produced by a pressure difference of only 1 millimeter of water.

Panellit Signs "Caretaker" Contract with Oil Company

Panellit Service Corp., the service and maintenance arm of Panellit, Inc., has signed a contract with Tidewater Oil Co. under which PSC becomes "caretaker" of Tidewater's giant "Flying A" refinery, the largest ever built from the ground up in the U. S. Besides furnishing Tidewater with what amounts to an instrument maintenance department, PSC will also supply adequate quantities of trained personnel for peak maintenance employment periods. Establishment of union agreements and complete information files on installed instruments is included in the agreement.

Other Developments

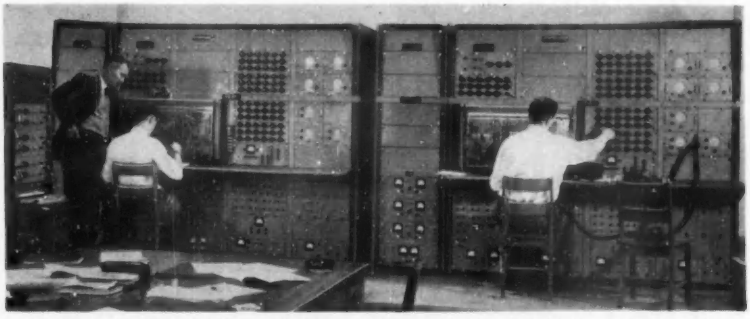
▶A contract between a manufacturer of typewriters and other office machines, and a maker of automatic equipment has laid the groundwork for a new line of automatic business machines. Under the agreement, **Royal McBee Corp.** of New York will manufacture and market the general-purpose equipment incorporating developments by **Tally Register Corp.** of Seattle. The agreement also provides that Royal McBee will manufacture certain computer components to be used as basic building blocks in special-purpose business machine systems to be developed by Tally Register. A sale of stock to Royal McBee cemented the agreement.

▶**Kee Enterprises, Inc.,** of New York, electronic instrumentation representatives, has established an analog computing center. Equipment will include **Philbrick Researches** modular computing and automatic control equipment, and photoelectric control apparatus manufactured by **Autotron, Inc.** Officers are Robert Crane and Samuel S. Egert.

▶A new company, **Gulton-Speidel, Inc.,** has been formed by **Gulton Industries, Inc.,** and the **Industrial Div.** of **Speidel Corp.** to market a series of new electronic products. Heading the new concern are: Leslie K. Gulton, president of Gulton, chairman; Paul Levinger, executive vice-president of Speidel, president; Richard Cotter, chief of Speidel's Industrial Div., vice-president, and Robert L. Pelz, attorney for Gulton, secretary-treasurer.

▶Another new company is **Dikewood Corp.,** formed at Albuquerque, N. M., by **Radiation, Inc.,** which will carry it as a consulting subsidiary for the electronics industry. Major emphasis will be on guided missiles and avionics. Officers are Sheldon H. Dike, president, and Walter D. Wood,

(Continued on page 183)



WHEN TWO COMPUTERS PUT THEIR HEADS TOGETHER—they often can solve problems too complex for one, says Computing Devices of Canada, Ltd., which recently installed these two Reeves REAC's in its Bells Corners, Ont., home. Included in the unit are 20 integrators, 36 summers, 40 invertors, and 14 servos. Power consumption exceeds 17 kw. A recording voltmeter stands at the extreme left.



If forward voltage drop is a problem in your diode circuitry...see the

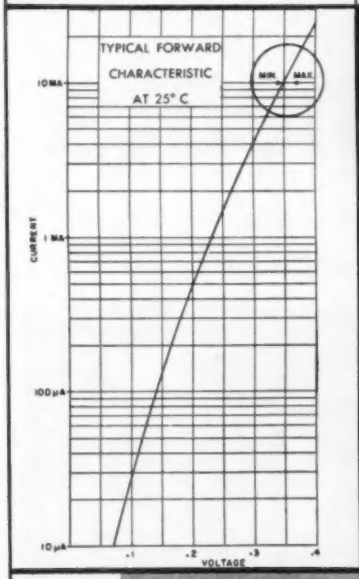
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Available now in production quantities for immediate delivery

with controlled forward voltage drop between 0.34 and 0.37V at the 10MA level



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Characteristics at 25° C	Forward voltage drop @ 10MA	
	Minimum	0.34V
	Maximum	0.37V
	Maximum reverse current at −10V	10UA
	Peak inverse voltage	60V
Maximum Ratings at 25° C	Maximum inverse operating voltage	50V
	Continuous DC forward current	100MA
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DR 385 exhibits fast transient response and similar diodes can be offered fully tested to your recovery conditions.

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Further information on DR 385, or any other RRco. diode type will be sent you at once upon request to section C-3.

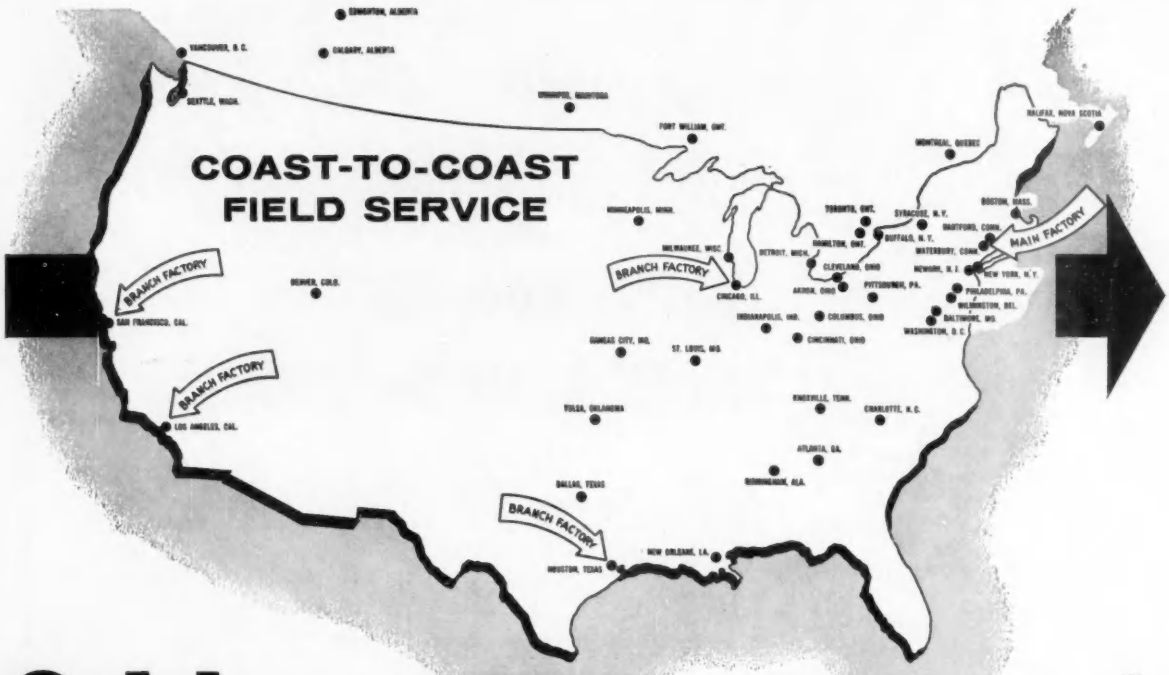
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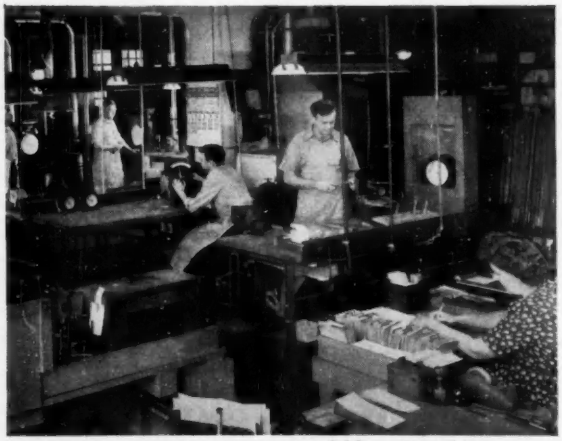


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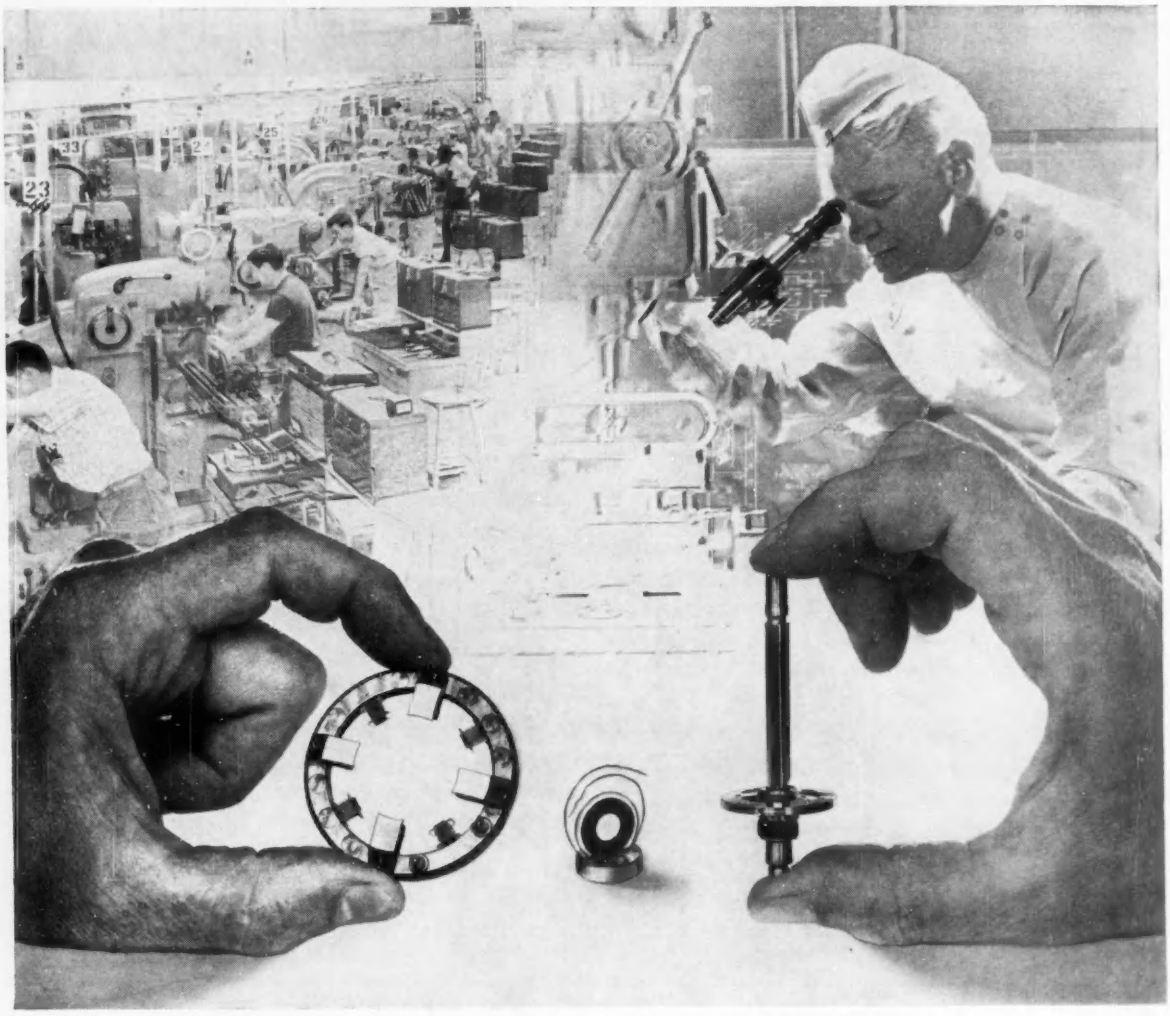
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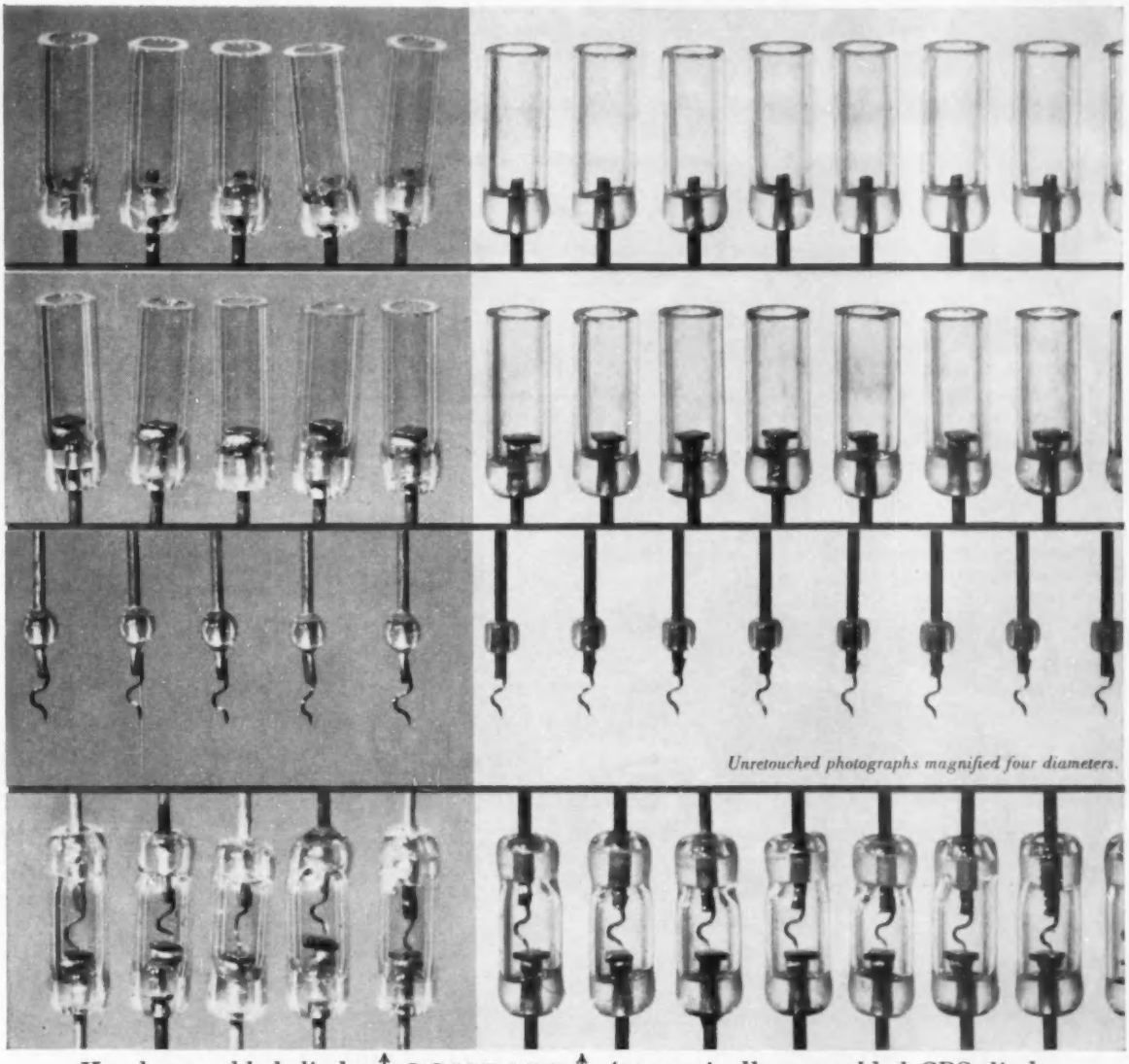
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The increasingly automatic assembly of electronic equipment is placing serious limitations upon component manufacturers. Rigid, tight tolerances must be maintained to avoid jamming the automatic machines. This spells automation for components, too.

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Gear Ratio	No-Load Speed	Nominal Voltage D.C.	Voltage Range D.C.	No-Load Current	Normal Speed	Normal Load OZ.IN.	Normal Current	Operating Temp. Range					
5.68:1	1800	28	24-32	0.4	1800	5.0	1.0	−55° To +85°C	13	3.777	P.M. GOVERNOR	FACE	13R-9102-08
17.9:1	600	28	24-32	0.4	600	12.0	1.0	−55° To +85°C	13	3.930	P.M. GOVERNOR	FACE	13R-9102-06
32.3:1	300	28	24-32	0.4	300	12.0	1.0	−55° To +85°C	13	3.935	P.M. GOVERNOR	FACE	13R-9102-02
67:1	150	28	24-32	0.4	150	12.0	0.6	−55° To +85°C	13	4.092	P.M. GOVERNOR	FACE	13R-9102-05
85:1	150	27.5	—	.25	130	50.0	0.7	−55° To +85°C	13	4.095	P.M.	FACE	13R-9101-11
109:1	100	28	24-32	0.4	100	32	0.6	−55° To +85°C	13	4.094	P.M. GOVERNOR	SYNCHRO	13R-9102-12
109:1	180	27.5	—	0.4	175	30	0.5	−55° To +100°C	13	2.843	P.M.	FLANGE	13R-9104-01
125:1	75-90	28	—	.25	70-85	20	0.3	−55° To +71°C	13	3.920	P.M.	FACE	13R-9101-13
157:1	60	28	24-32	0.4	60	12.0	0.6	−55° To +85°C	13	4.095	P.M. GOVERNOR	FACE	13R-9102-03
285:1	48	35	—	.25	48	160	0.6	−55° To +71°C	13	4.038	P.M.	FACE	13R-9103-01
333:1	30	28	24-32	0.4	30	12.0	0.6	−55° To +85°C	13	4.317	P.M. GOVERNOR	FACE	13R-9102-04
410:1	15	27	25-29	0.3	15	8.0	0.3	−55° To +85°C	13	4.400	P.M. GOVERNOR	FACE	13R-9102-11
1043.8:1	5-10	27	24-30	0.15	7	30	0.2	−55° To +71°C	13	4.458	P.M. BRAKE	FACE	13R-9105-01
1044:1	5-10	27	24-30	0.15	7	30	0.2	−55° To +71°C	13	3.910	P.M.	FACE	13R-9101-12
2214:1	3-4	6	—	1.2	3.4	30	1.2	−55° To +71°C	13	4.454	P.M.	FACE	13R-9101-04
3241:1	5.5	35	—	.35	5.5	16	0.4	−55° To +71°C	13	4.454	P.M.	FACE	13R-9101-03
5933:1	1.3	30	—	.13	1.3	30	0.15	−55° To +71°C	13	4.816	P.M.	FACE	13R-9101-10
21,707:1	2-3	120	—	.25	2-3	12	0.25	−55° To +71°C	13	3.475	P.M.	FLANGE	13R-9101-16
322:1	80	110	—	0.2	30	240	0.3	−55° To +71°C	15	3.815	SPLIT SERIES	FLANGE	15R-9201-01
407:1	22	27	—	0.2	20	8	0.2	−20° To +50°C	15	3.989	SPLIT SERIES	SYNCHRO	15R-9201-03
433:1	30	26	—	0.6	25	260	1.2	−50° To +80°C	15	3.110	SHUNT	FACE	15R-9201-02
955:1	33	27	—	0.6	12-18	420	1.0	−55° To +50° C	15	4.419	SPLIT SERIES	FLANGE	15R-9201-00
28:1	240	27.5	24-29	0.65	240	40	1.3	−10° To +71°C	17	5.315	SHUNT GOVERNOR	SYNCHRO	17R-9251-01
4.26:1	1800	28	—	0.6	1800	12	1.85	−30° To +55°C	24	4.840	SHUNT GOVERNOR	FACE	24R-9451-01

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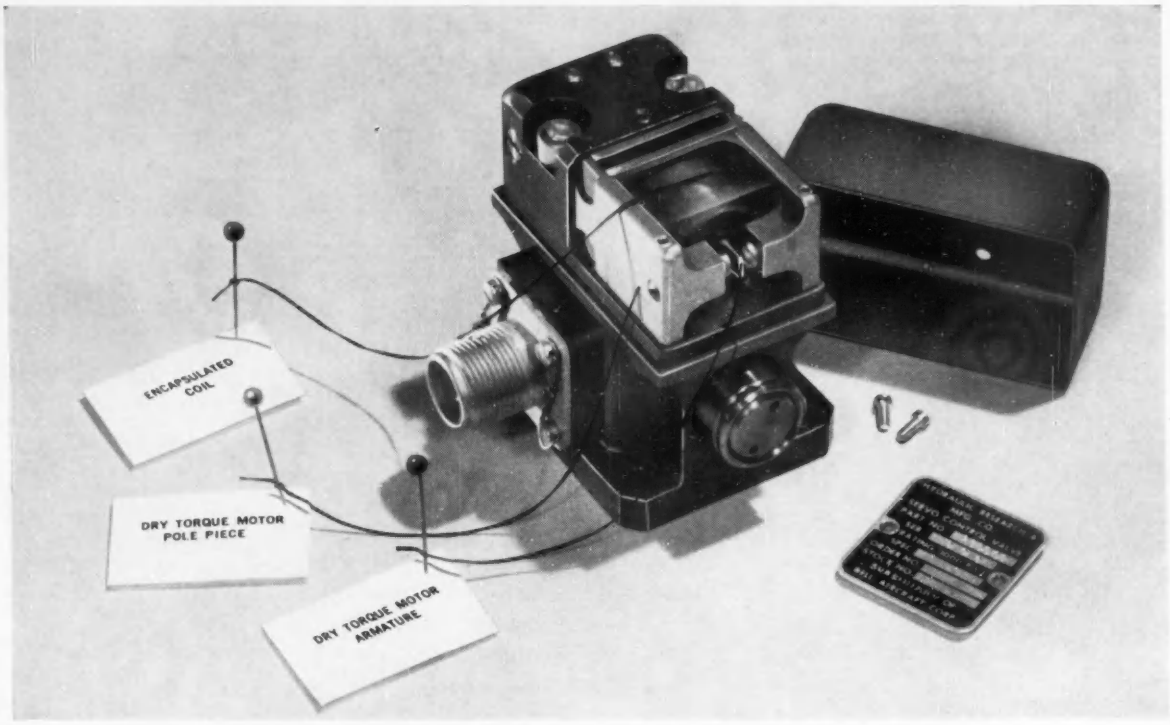
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Subsidiary of Bell Aircraft Corp.

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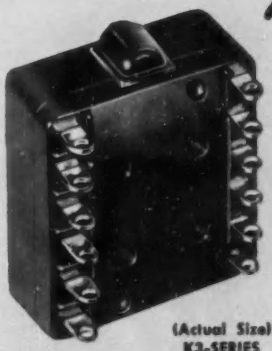

MANUAL SHUT OFF


PRIORITY


PRESSURE SWITCH


PRESSURE REDUCER

PRECISION HYDRAULIC VALVES AND COMPONENTS FOR FLIGHT CONTROL SINCE 1943



(Actual Size)
K3-SERIES

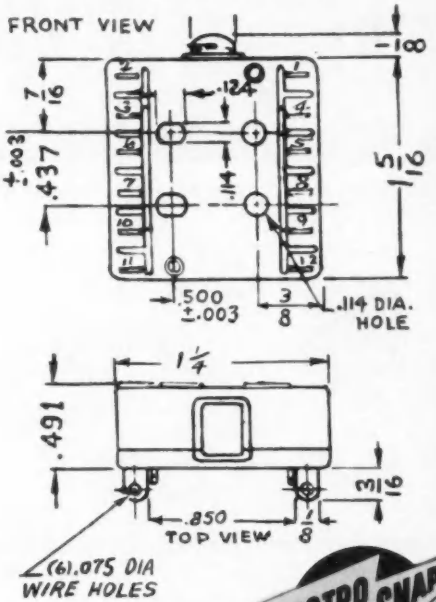
TRIPLE-POLE SWITCH

OPERATING CHARACTERISTICS

CONTACT ARRANGEMENTS:
K3-4—TRIPLE-POLE, DOUBLE THROW
K3-2—TRIPLE-POLE, NORMALLY OPEN
K3-1—TRIPLE-POLE, NORMALLY CLOSED

ELECTRICAL RATING:
15 AMP 125/250 V.A.C.
15 AMP 30 V.D.C. RESISTIVE
10 AMP 30 V.D.C. INDUCTIVE

PROBABLE MECH. LIFE.....1,000,000 OPS
PROBABLE ELEC. LIFE..... 500,000 OPS
AMBIENT TEMP. RANGE.....—100° TO +275° F.*
*(—100° to +375°F. available)



New ELECTRO SNAP SIMULTANEOUS

TRIPLE-POLE SWITCH

for interrupting 3-phase,
110 V, 400 cycle AC circuits

6-CIRCUIT CONTROL — in a small package.
Makes possible a wide variety of circuit combinations.

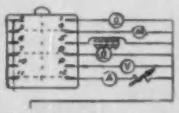
SIMULTANEOUS "MAKE & BREAK" ACTION
Permits unusual applications, reduces arcing, prolongs switch life and increases electrical capacity.

This completely new Electro-Snap triple-pole switch simultaneously reverses current flow through three windings of a 3-phase motor up to 1 H.P. and interrupts other types of multi-switching installations. Instantaneous snap-action of the three poles is independent of the speed of actuation — even extremely slow moving cams can be used.

The K3-Series offers designers a wide variety of 3-phase circuit hookups for servo-controls, to limit movement of machine members and as a start-and-stop switch which formerly were possible only with complicated relays or a number of separate switches. A large selection of standard actuators is available.

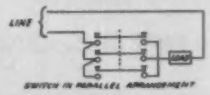
LOOK WHAT YOU CAN DO WITH IT!

Control Six Circuits with ONE Snap



Used in motor control device switch, when actuated, turns on the red light on No. 1, the solenoid on No. 5, the voltmeter on No. 9 and turns off the motor on No. 4, the green light on No. 8 and the furnace and ammeter on No. 12.

Wire Movable Poles in Series for High Voltage or in Parallel for High Current

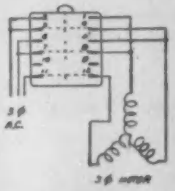


With the switch wired in parallel arrangement, the current is divided into 3 paths through the switch. This permits the switch to be used with a load rated up to 3 times the ampere rating of the switch.

With the switch wired in series arrangement, the current has only 1 path through the switch. The multiple breaks in the current path permits the switch to be used where the line voltage is rated up to 3 times the voltage rating of the switch; ampere rating not affected.

Start and Stop Three-Phase Motors

Completely disconnect all current supplied to a 3-phase motor by interrupting 3 phases simultaneously with one snap.



ELECTRO-SNAP
SWITCH AND MFG. CO.
4248 West Lake Street • Chicago 24, Illinois

MODERN DESIGN IN A COMPLETE LINE OF SWITCHES


Sub-Miniature Switch


Double-Pole Switch


One-Way Limit Switch


Immersion-Proof Switch


Hermetically-Sealed Limit Switches

A
NEW
NAME

KINTEL

for **KAY LAB** *products*



The same company, the same engineering and manufacturing facilities, the same world-wide staff of field engineers, but a new name more descriptive of the Company and its products.

LOOK FOR **KINTEL** ON:



UNIVERSAL DC MICROVOLTMETERS | INDUSTRIAL TELEVISION EQUIPMENT | MICROVOLT LEVEL BROADBAND DC AMPLIFIERS | BROADCAST TELEVISION EQUIPMENT | ABSOLUTE DC POWER SUPPLIES AND METER CALIBRATORS

On these and many other electronic products the name **KINTEL** means outstanding instruments and television equipment.

KINTEL
[KAY LAB]

Representatives in all major cities

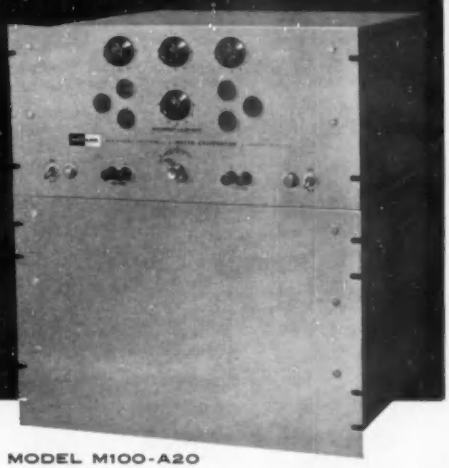
Write, wire, phone today for demonstration

ELECTRONICS FOR COMMUNICATION · MEASUREMENT · CONTROL

5725 KEARNY VILLA ROAD · SAN DIEGO 11, CALIFORNIA · BROWNING 7-6700

Need accurately controlled

POWER?



MODEL M100-A20

USE KINTEL ABSOLUTE DC POWER SUPPLIES AND METER CALIBRATORS

— STANDARD CELL ACCURACY

— 0.01% STABILITY

— <0.5 MILLIVOLT RIPPLE

— 0.002% REGULATION

— <0.2 MILLISEC RESPONSE TIME

— 21 MODELS: 0-2000V, 0-2 AMP

KINTEL's unique chopper stabilized circuit constantly compares the output with an **internal standard cell,** providing stability, accuracy, and dynamic characteristics **without equal.** Direct reading calibrated dials provide instant voltage selection. Both current and voltage regulated models available. Ideal wherever a general purpose precision voltage or current source independent of line or load is required . . . for laboratory and production meter calibration, computer reference, secondary standard, DC bridge supply, transistor testing, circuit design, nucleonics instrumentation, null voltmeter . . .

SPECIFICATIONS

POWER SUPPLY: Short Time Stability (several hours), ±0.005%—Long Time Stability, ±0.01%—Output Voltage Calibration, ±0.02%—Output Impedance, < 0.01Ω at DC, <0.05Ω to 200 kc—Output Hum and Noise, < 0.5 millivolt—Load Regulation Factor, ±0.01%—Line Regulation Factor, ±0.002%.

METER CALIBRATOR: Same as Power Supplies with following exceptions for models which go to zero volts: Calibration Tolerance, ±0.05%—Hum and Noise, < 2 millivolts—Line Regulation Factor, ±0.01% of full scale.

KINTEL
[KAY LAB]

Representatives in all major cities

Write, wire, phone today for demonstration

5725 KEARNY VILLA ROAD • SAN DIEGO 11, CALIFORNIA • BROWNING 7-6700

ALLIED CONTROL'S

New

CRADLE RELAYS

These new telephone type relays meet the requirements of modern equipment for a small versatile and economical relay. Designed and manufactured by Siemens & Halske Company, Germany, the cradle relay series are now available from Allied Control. In the near future these relays will be produced by Allied with the technical assistance of Siemens & Halske. • For complete information on these relays write for Bulletin 52.

Specifications

Pull-in Power at 25° C:
.035 watt to .140 watt

Contact Arrangements:
up to 6 make or 6 break or 4 pdt

Contact Rating:
1 or 5 amp, 30v d-c or 115v a-c

Max. Coil Loading:
1.5 watts

Coil Voltages:
From 1v d-c to 140v d-c

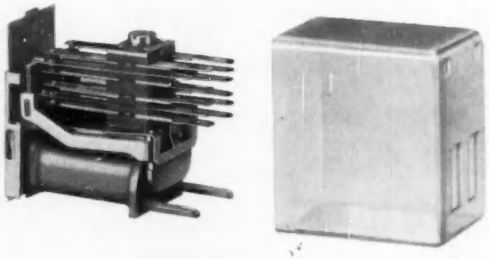
Coil Resistance:
From 1.3 ohms to 15,000 ohms

Speed of Operation:
10 ms max. at 1 watt

Shock: 25 G's

Vibration:
10-55 cps at .062″ double amplitude
55-500 cps 8 G's

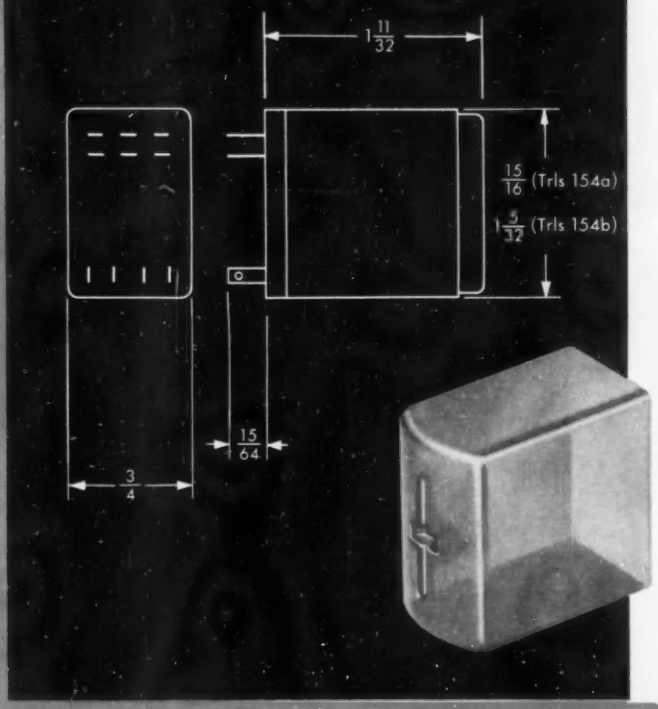
Actual Size



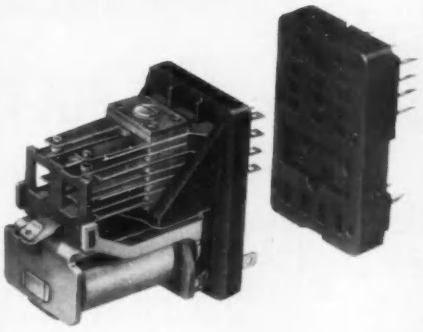
ALLIED TYPE Trls 151
Available in two sizes (x or y) with solder terminals and transparent dust cover.

For Types Trls 151 and 151H low capacitance wire contact pile-ups are also available.

AL174

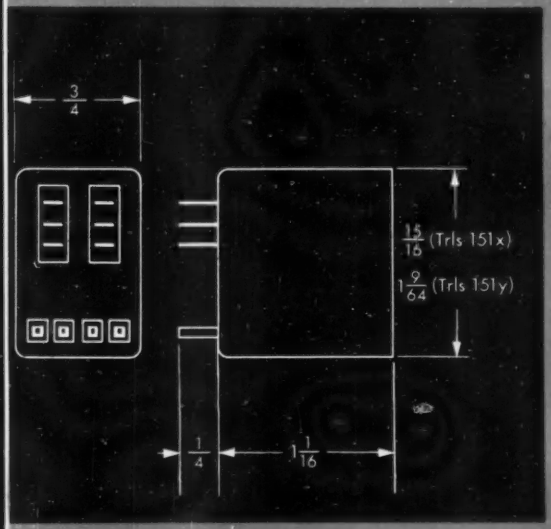


ALLIED
TYPE Trls 154
Available in two sizes (a or b) with plug-in base, transparent dust cover, and special socket.



Actual Size

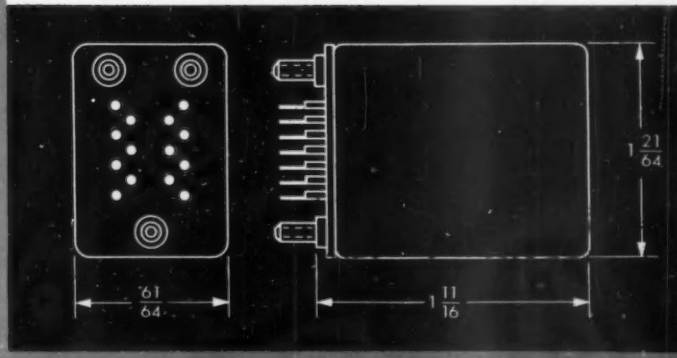
DIMENSIONS SHOWN ARE MAXIMUM





ALLIED
TYPE Trls 151H
This is an hermetically sealed version of Allied's Type 151.

Actual Size

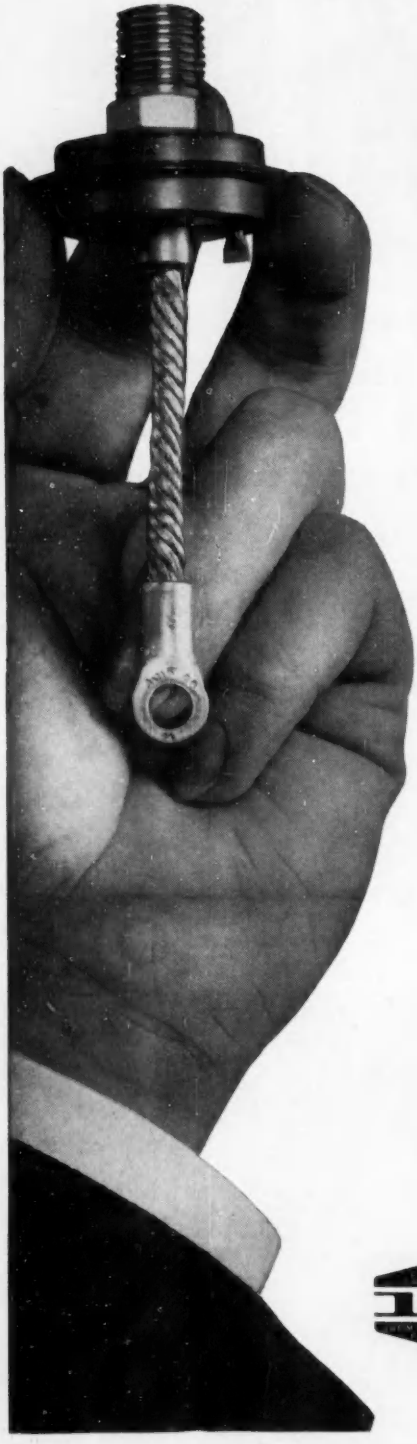


ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N. Y.

DESIGN PROBLEM:

MORE RECTIFIER POWER PER INCH OF SPACE...



SOLVED AT LOWER COST—

with greater reliability—by this new General Electric High Current Silicon Rectifier

Packing *greater* rectifying capacity into *less* space—with maximum reliability and efficiency—is becoming standard practice with General Electric Silicon Rectifiers. And the cost of these G-E High Current Silicon Rectifiers, with their unmatched performance, is now actually less than that of comparable rectifying devices.

REQUIRE MINIMUM SPACE

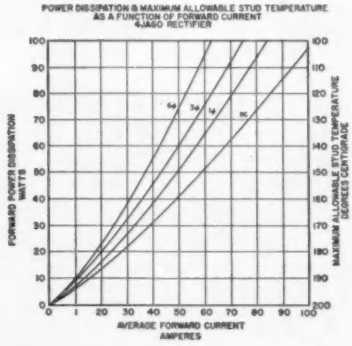
The Silicon Rectifier pictured here in full size has ratings up to 85 amps... yet measures less than 1⅝ inches in diameter. It operates, or can be stored, safely at temperatures from 200° to –65° centigrade and checks out above 99% in efficiency. Maximum peak inverse voltage is 300. Silicon rectifiers of higher ratings are on the way.

Produced by the alloy technique developed in General Electric laboratories, these high-capacity rectifiers show no deterioration in rectifier characteristics during extended life tests at full rated condition. The silicon element is hermetically sealed in a steel housing for protection against moisture, fumes, dust, vibration, and corrosion. Effective cooling is assured by the tapered thread "plumbing type" stud that screws tight into heat sink or cooling fin.

WORK ANYWHERE... ON ANY APPLICATION

General Electric Silicon Rectifiers are installed in any position or location, and work in any rectifier operation. They are now serving in many applications such as arc furnaces, welding, and protection against cathodic erosion.

They are available now in different voltage ranges, and meet rigid military specifications. For detailed information, consult your local General Electric representative, or write to *General Electric Company, Semiconductor Products, Section S1637, Electronics Park, Syracuse, New York.*



TYPICAL APPLICATION GENERAL ELECTRIC HIGH CURRENT SILICON RECTIFIER

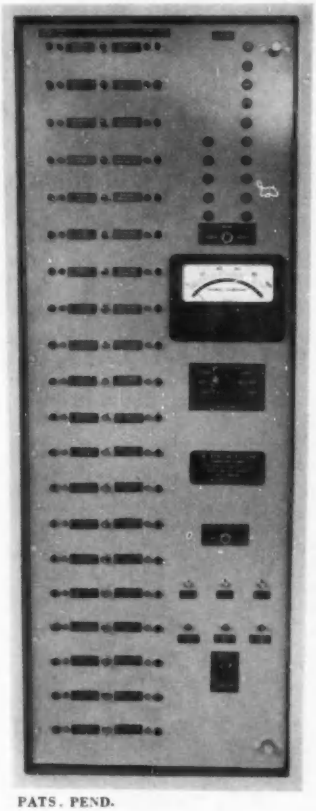
CIRCUIT	Three Phase Bridge Rectifier, Resistive Load.
DC OUTPUT	280 Volts, 215 amperes, 60 kilowatts.
RECTIFIER LOSSES	Approximately one percent (½ kilowatt).
COOLING REQUIRED	One 6½-inch square, ⅛" thick copper fin for each of six rectifying units when used with 2000 fpm 30°C forced air. Free convection cooling may be utilized by increasing the fin area.
VOLUME	Total volume of rectifiers and fins—less than ⅓ of a cubic foot.

Progress Is Our Most Important Product

GENERAL ELECTRIC

KYBERNETES PRESENTS
ANOTHER COMPLETELY NEW CONCEPT IN INSTRUMENTATION

Temperature Indicator Monitor



PATS. PEND.

TEMPERATURE INDICATOR MONITOR

FOR MONITORING 40 TO 80 THERMOCOUPLES

- WITH POTENTIOMETRIC ACCURACY
- INCORPORATING A BUILT-IN T. I. (TEMPERATURE INDICATOR)
- COMPLETELY ELECTRONIC WITH NO MOVING PARTS
- ALL IN ONE COMPACT INSTRUMENT*

TIM has been made possible through the incorporation of advanced techniques developed for The Kybernetes Data Logger. The three major components involved are the all-electronic potentiometric type amplifier with ground isolated input and high noise rejection factor, the alarm comparator, and the chopper stabilized power supply. These units have maximum long term drifts of .06%, .01% and .01% respectively.

FEATURES OF THIS INSTRUMENT INCLUDE —

- Non-interruption of alarm monitoring during readout on the T.I.
- Continuous alarm scanning at the rate of 5 points per second.
- Individual hermetically sealed plug-in relays for scanning to provide many years of reliability.
- Advanced standardizing technique eliminating the use of a standard cell.
- Accurate setting of the individual alarm set points, read directly on the indicator, provides operational simplicity.
- 1° readability on the T.I. through incremental ranging in 100 degree steps.
- Imperceptible meter error through range suppression in potentiometric type amplifier circuit.
- Alarm memory for momentary alarms.
- Elimination of conventional lockup relays in annunciator circuits.
- Automatic operational check of all circuits including continuity of thermocouples.
- Compact design — 21″ wide, 44″ high and 16″ deep.

**The power supply is packaged separately.*

TOTAL NET PRICE: 40 point unit $4,000 F.O.B. New York, N. Y. $50 per additional point to a maximum of 80 points per unit.
YOURS ON REQUEST: Technical Bulletin #109 fully describing TIM.

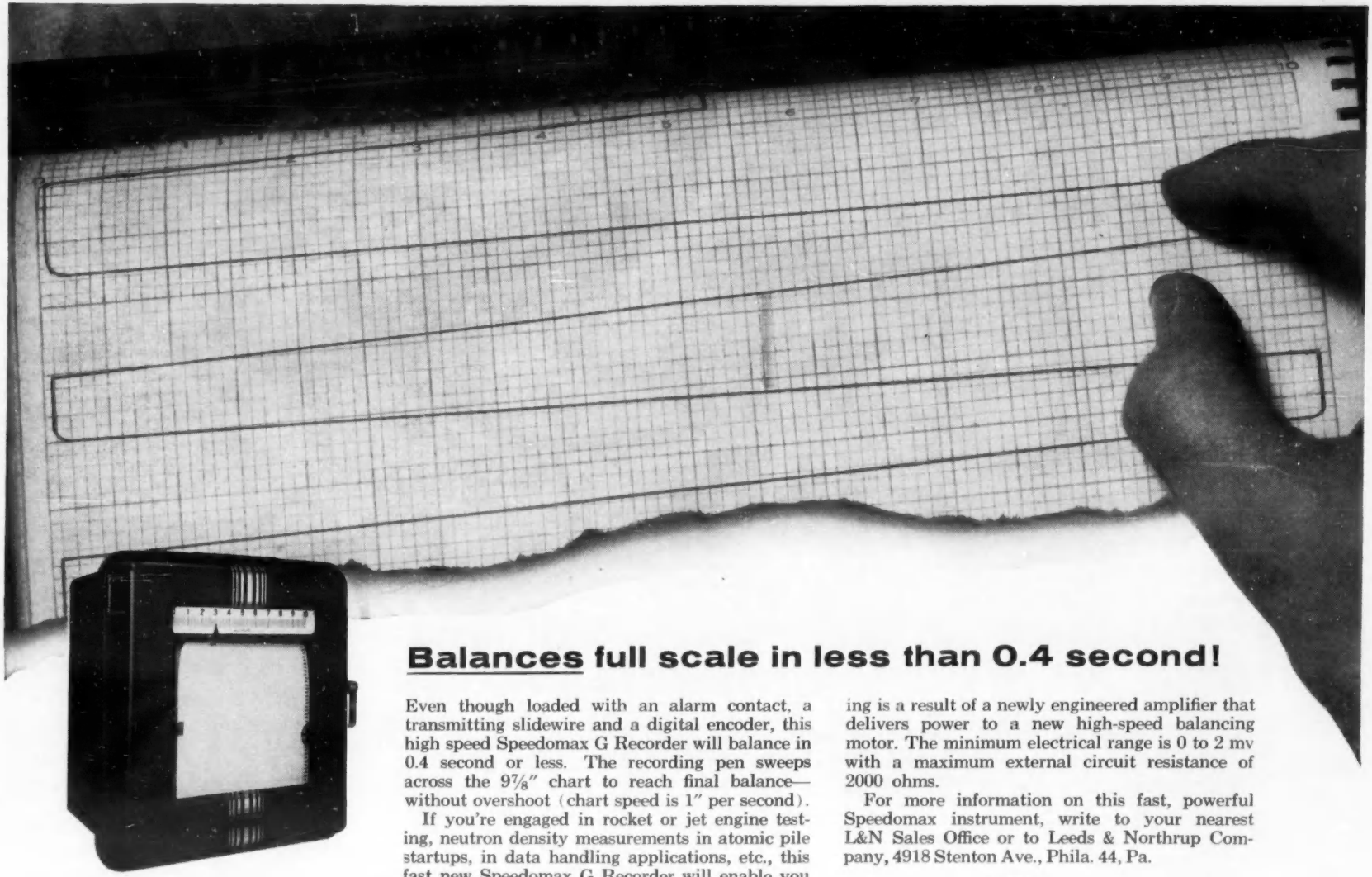
THE

KYBERNETES®

CORPORATION

A DIVISION OF SELF WINDING CLOCK CO., INC
For 70 years leader in time standards and precision engineering

SALES AND EXECUTIVE OFFICES:
9 EAST 40TH STREET, NEW YORK 16, N. Y.



Balances full scale in less than 0.4 second!

Even though loaded with an alarm contact, a transmitting slidewire and a digital encoder, this high speed Speedomax G Recorder will balance in 0.4 second or less. The recording pen sweeps across the 9⅞″ chart to reach final balance—without overshoot (chart speed is 1″ per second).

If you're engaged in rocket or jet engine testing, neutron density measurements in atomic pile startups, in data handling applications, etc., this fast new Speedomax G Recorder will enable you to measure and record extremely fast changes in the d-c millivolt signal under test.

This fast balancing speed with instrument loading is a result of a newly engineered amplifier that delivers power to a new high-speed balancing motor. The minimum electrical range is 0 to 2 mv with a maximum external circuit resistance of 2000 ohms.

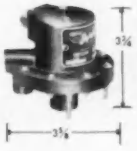
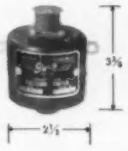
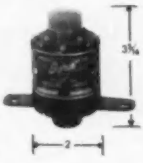
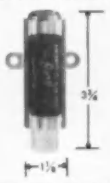
For more information on this fast, powerful Speedomax instrument, write to your nearest L&N Sales Office or to Leeds & Northrup Company, 4918 Stenton Ave., Phila. 44, Pa.

LEEDS Instruments NORTHRUP Automatic Controls • Furnaces

CLIP AND FILE

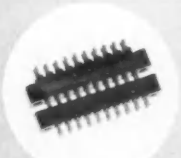
quick reference chart for most often specified

GORN SWITCHES & CONNECTORS

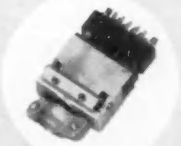
A Complete Line of Tested Pressure and Float Switches for Missiles and Aircraft	Vacuum & Absolute Pressure Switch	Altitude Switch	Differential Pressure Switch	Low Pressure Switch	Medium Pressure Switch	High Pressure Switch	Horizontal Float Switch
							
Catalog Series	GAB1000*	GB300*	GP16000*	GP8000*	GP8060*	GPP12000*	GHF5400†
Weight	2.3 oz.	1.8 oz	16 oz.	8.5 oz.	7 oz.	4.5 oz.	7.5 oz.
Actuation Setting Range of Tested Available Models	3 to 25 psia	5000 to 60,000 feet	1" W.C. to 10 psig differential	1 to 100 psig	1 to 800 psig	75 to 3000 psig	On Horizontal Center Line
Max. Oper. Press. Proof Pressure Burst Pressure	30 psia 45 psia 60 psia		10 psig 20 psig 30 psig	100 psig 200 psig 600 psig	800 psig 1200 psig 2400 psig	3000 psig 4500 psig 7500 psig	
Electrical Rating	SPDT 18-30 VDC 2.5A. Ind.	SPDT 18-30 VDC 2.5A. Ind.	SPDT 18-30 VDC 2.5A. Ind.	SPDT 18-30 VDC 5A. Ind.	SPDT 18-30 VDC 2.5A. Ind.	SPDT 18-30 VDC 2.5A. Ind.	SPDT 18-30 VDC 2.5A. Ind.
Temperature Ratings Available	–65 to 160F –65 to 275F –65 to 400F**	–65 to 160F –65 to 275F –65 to 400F**	–65 to 160F only at present	–65 to 160F –65 to 275F –65 to 400F**	–65 to 160F –65 to 275F –65 to 400F**	–65 to 160F –65 to 275F –65 to 400F**	–65 to 160F –65 to 275F –65 to 375F
Vibration Ratings up to 10G	5-500 5-2000 CPS	5-500 5-2000 CPS	5-500 5-2000 CPS	5-500 5-2000 CPS	5-500 5-2000 CPS	5-500 5-2000 CPS	5-500 CPS
Explosion Ratings to Specification	MIL-E-5272A	MIL-E-5272A	MIL-F-8615	MIL-F-8615	MIL-F-8615	MIL-E-5272A	MIL-F-8615

*Switches can be supplied either factory pre-set or with means for external adjustment. **Presently undergoing test.
†Also available in vertical, single, double and triple float arrangements.

GORN GOLD SEAL CONNECTORS In Melamine Or Plaskon Alkyd



GRA Series – Miniature Power Connectors for high voltage and current capacity; for No. 16 AWG.



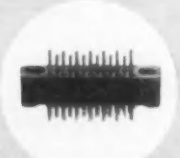
GMRD Series SNAP-LOC – Available in GM series; for quick snap-action, separation and harness locking; contacts 7 to 50.



GH Series – Hex Miniature available with lock ring, spring and nut; hood and cable clamp; from 18 to 20 AWG; contacts 4, 5, 7, 9; also hermetically sealed.



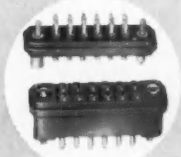
GPC Series – Printed Circuit; will mate with printed circuit boards from .061 to .071 thick; with solder and solderless terminations; contacts 6, 8, 10, 12, 15, 18, 22.



GM Series–Miniature Rack and Panel from No. 18 to 20 AWG; contacts 7, 8, 9, 14, 18, 20, 21, 26, 34, 41, 50;* also hermetically sealed.



GHR Series – Approved at 2000* for 5 min. per.; hood and cable clamp protects against vibration; for No. 16 AWG; contacts 1, 2, 3, 5.



GRD Series–Rapid Disconnect; spring loaded receptacle; polarized guides prevent mis-mating; from 14 to 16 AWG; contacts 12, 18, 34.



GB Series – Heavy duty, high voltage connectors for aircraft power and communication equipment; can be supplied with any AN size 36 shell.

Enlargements of this advertisement available on request, for use as wall chart. Write:

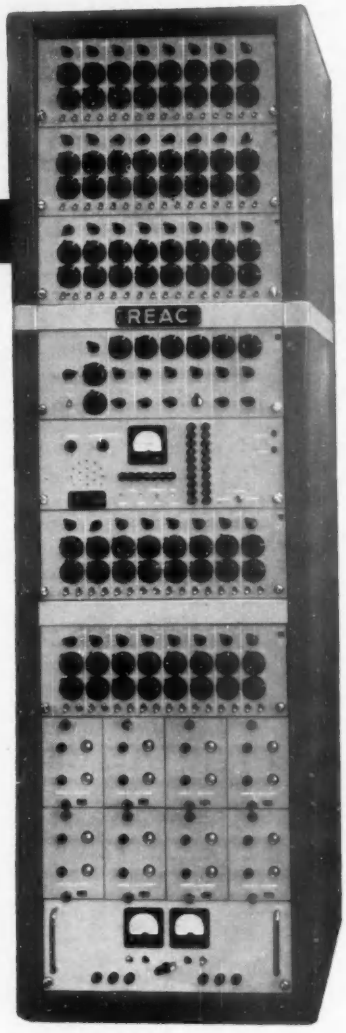
Gorn ESTABLISHED 1923

GORN ELECTRIC CO., INC. STAMFORD, CONNECTICUT

Generation of Functions of *Two or More* Variables

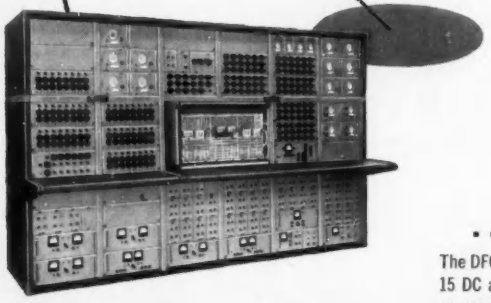
with the

400 series REAC®



DIODE FUNCTION GENERATOR

- Allows direct generation of slopes up to 12 volts/volt without paralleling diode segments.
- 10-turn potentiometers for both "slope" and "break point" give excellent resolution. Still further improvement in resolution is obtained by splitting slope adjustment into two ranges.
- 1000-division direct read-out 10-turn dials permit logging of function for fast reproduction later.
- Flexible switching system allows number of segments per channel to be varied from 2 to 30.
- Built-in calibration circuit permits functions to be set up quickly and easily without use of external plotting board.



See our Booths 1702-1708
I.R.E. SHOW
New York Coliseum
March 18-21, 1957

3RV57

. . . a complete self-contained unit

The DFG-401 is a completely self-contained unit consisting of 5 channels of function generation, 15 DC amplifiers (with VTVM and all control circuits for monitoring and balancing), and all necessary power supplies (except relay and reference voltages). In the event that any amplifiers supplied are not needed in the problem, they can be made available in groups at the patchbay as inverters with one gain of one.

This unit is ideal for the addition of up-to-date diode function generation equipment to an existing analog computer installation.

Electronic generation of functions of two or more variables is another outstanding Reeves contribution to the flexibility and efficiency of the electronic analog computer. Before installing new equipment, it will pay you to consult us. A comprehensive new REAC "400" series computer technical brochure will be sent upon request.

REEVES INSTRUMENT CORPORATION
A Subsidiary of Dynamics Corp. of America, 209 East 91st St., New York 28, New York

Reeves INSTRUMENT CORPORATION

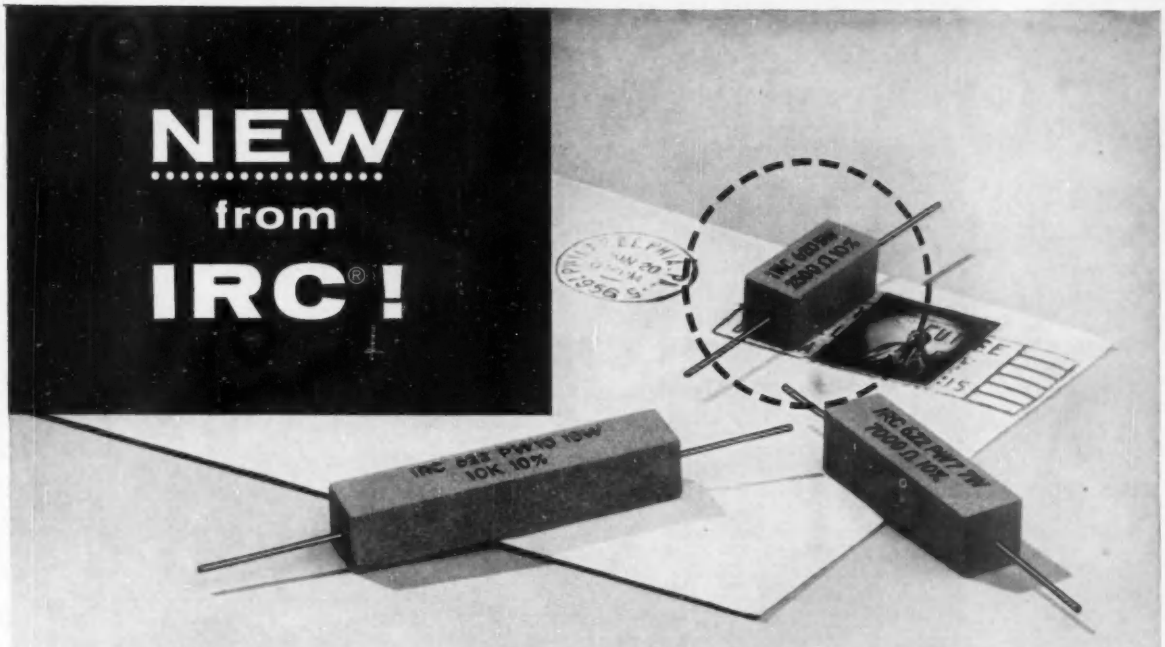

REAC Analog Computers


Precision Floated Gyros


Precision Resolvers and Phase Shifters


Servo Mechanical Parts

NEW from IRC®!



Superior Power Resistor Features in a Low Cost 5-Watt Unit

The new IRC PW-5 Wire Wound Resistor now opens up new possibilities for miniaturization and cost savings in resistance capacitance filters, radio and TV circuits, bridge circuits, attenuator networks, and many other circuits. With this new 5-watt resistor, you can now obtain the superior insulating and high temperature characteristics as found in IRC's famous PW-7 and PW-10 units. The PW-5 also offers you the same extra terminal security resulting from simultaneous assembly of element, leads, and terminal clips in one automatic operation. This latest addition means that you now can specify IRC for *all* medium power requirements.

LOOK AT THESE FEATURES

- **PW-5 saves space . . . only ⅞"x⅜"x1½"**
- **PW-5 installs easily . . . rectangular case with axial leads**
- **PW-5 covers wide range . . . from 0.24 ohm to 3300 ohms**
- **PW-5 stands high temperatures . . . operates at 60% rated load even at 100° C. ambient**

INTERNATIONAL RESISTANCE CO.
Dept. 182, 401 N. Broad St., Phila. 8, Pa.

In Canada: International Resistance Co., Ltd., Toronto, Licensee

Send bulletin describing new 5-Watt, 7-Watt, and 10-Watt Power Resistors.

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ STATE_____

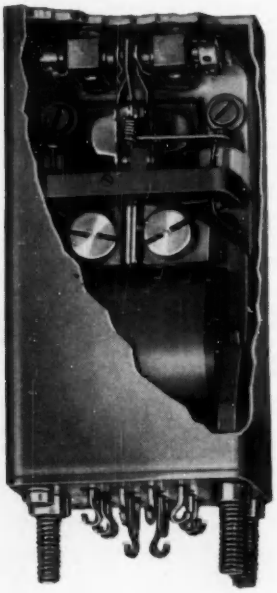
Insulated Composition Resistors • Deposited and Boron Carbon Precistors • Power Resistors • Voltmeter Multipliers • Ultra HF and Hi-Voltage Resistors.

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IRC®

ALLIED'S NEW



Allied Types
Trls 163-169

Actual Sizes

This new polarized relay, designed and manufactured by Siemens & Halske Company of Germany, is now available from Allied Control, and in the near future will be produced by Allied with the technical assistance of Siemens & Halske.



Allied Types
Trls 193-199



Trls 163-169 with SOLDER TERMINALS

Trls 193-199
with OCTAL BASE

AL 173

Sealed POLARIZED RELAYS

Specifications for Allied's Types TrIs 163-169 and TrIs 193-199

Type Number			TrIs 163 TrIs 193	TrIs 164 TrIs 194	TrIs 165 TrIs 195	TrIs 166 TrIs 196	TrIs 167 TrIs 197	TrIs 168 TrIs 198	TrIs 169 TrIs 199
Description		Positions	2		3	2	2	3	2
		Operation	Magnetic Latch						
			High Contact Pressure	High Sensitivity	Null Center	Magnetic Latch	Spring Biased	Null Center	Spring Biased
Contact Arrangement			SPDT		SPDT	DPDT	SPDT	DPDT	DPDT
"Operate" Excitation (Std.)		Amp. Turns	7	2	2.2	5.5	5	4	15
"Operate" Power	TrIs 163-169	μ Watts	500	40	50	300	250	160	2250
	TrIs 193-199		610	49	61	375	300	195	2750
"Working" Excitation		Amp. Turns	15	4	6	10	10	10	25
"Release" Excitation		Amp. Turns			2.2		2.4	4	5
Max. Rate of Operation		Oper./Sec.	200	200	200	200	100	200	100

Shock and Vibration: The degree of shock and vibration resistance is related to the type of operation, the adjustment, the coil input power and the application. Contact Allied Control for ratings for your specific application.

Contacts:	Silver, General Purpose 2 amp., 28v d-c resistive load
	Platinum Alloy A. Low-Level Applications up to .5 amp.
	Platinum Alloy B. Heavy Duty Applications above .5 amp.
	Max. Continuous Current 5 amps.

Dielectric Test Voltage	Coil to Frame	500v rms.
	Contact to Contact	350v rms.
	Contact to Frame	500v rms.
	Winding to Winding	150-500v rms.
Standard Coils	Resistances from 1.1 to 18,000 ohms	
	Max. number of windings	3
	Max. Continuous Loading	1 watt
Temperature	Max. Ambient	85°C



ALLIED CONTROL



ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N.Y.

How to simplify control problems

Keep systems flexible, carry small inventory, cut maintenance cost with the **Bailey Building Block Method** of instrumentation and control.

What is the Bailey Building Block Method? It's using standardized Bailey measuring, transmitting, and controlling components and combining them into any system you need. Components can be added as needed . . . removed and reused elsewhere . . . recombined into another system when the need changes. It's flexibility plus!

It's all based on the simple fact that a Bailey instrument or control component doesn't care if the measured variable is steam flow, tank level, or tower temperature, to pick just three examples. System components—transmitters, receivers, relays, selector stations, power units—are standardized for multi-purpose use.

A spare component can be used in any one of many systems. Gone are delays waiting for shipments of special parts. Gone are large inventories of spares and parts. Simplified is the training of men for maintenance.

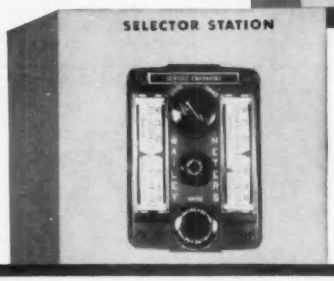
There are many exclusive features and advantages of the individual components used in the Bailey Building Block Method. And there's much more to the Building Block story itself.

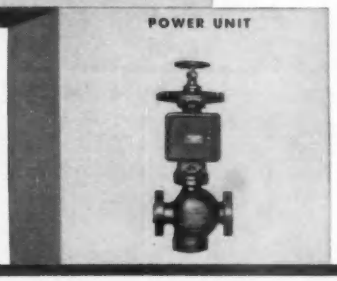
For further details, call our local district office or write us at Cleveland. Our engineers will be glad to prove how the Building Block approach will save you money and simplify your instrument and control problems.











G36-1

BAILEY BUILDING BLOCK METHOD

BAILEY METER COMPANY
1079 IVANHOE ROAD, CLEVELAND 10, OHIO
In Canada—Bailey Meter Company Limited, Montreal

RESULTS IN: FLEXIBILITY, SIMPLICITY, ECONOMY

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STANDARD HIGH GAIN MAGNETIC AMPLIFIERS



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YOUR LARGEST AND MOST DEPENDABLE SOURCE

4 WEEKS' DELIVERY

(many can be shipped directly from stock)

	BULLETIN NUMBER	AC SUPPLY	DC POWER OUTPUT (SEE NOTE 3)				DC CONTROL AMP-TURNS	RESPONSE TIME 3 CYCLE 63%		NO EXTERNAL R		SEE NOTE 4		POWER GAIN (500 TURN WDNG)		CONTROL WINDINGS (SEE NOTE 5) WINDING 5-6 100 TURNS		WINDING 7-8 500 TURNS		BUL. NO.
		Volts	Watts	DC Volts	DC Amps.	Load Ohms		Input Watts	Ohms N^2	Input Watts	Cycles	C^1	C^2	3-63%	No External R	Ohms	Max. Amp.	Ohms	Max. Amp.	
1 PHASE POWER SOURCE (NOTE 1)	2502	120	3.9	37	.105	350	4	.013	.0011	.0030	13	.0027	.5	290	1200	2.4	0.58	70	0.12	2502
	2503	120	6.7	43	.155	275	4	.023	.0019	.0025	26	.0047	.5	300	2700	2.0	0.58	58	0.12	2503
	2504	120	13	43	.30	145	5	.038	.0015	.0063	46	.0037	.6	340	2050	2.5	0.73	54	0.15	2504
	2505	120	23	46	.50	92	5	.057	.0023	.0060	62	.0055	.6	400	3940	2.4	0.73	66	0.15	2505
	2506	120	47	50	.94	53	5	.098	.0039	.0060	95	.0094	.6	480	7850	2.4	0.73	73	0.15	2506
	2507	120	80	53	1.5	35	7	.125	.0026	.0049	67	.0059	.7	640	16300	1.0	0.92	28	0.18	2507
	2508	120	130	57	2.3	25	7	.17	.0035	.0049	82	.0080	.7	760	26500	1.0	0.92	30	0.18	2508
	2509	120	190	58	3.3	18	8	.24	.0037	.0071	84	.0083	.75	800	26800	1.1	0.92	30	0.18	2509
	2510	120	280	60	4.7	12	8	.33	.0051	.0080	104	.0115	.75	850	35000	1.3	0.92	34	0.18	2510
3 PHASE POWER SOURCE (NOTE 2)	2522	240	19.5	110	.177	620	5.5	.035	.0015	.0180	6	.0037	.4	520	1080	7.2	0.58	210	0.12	2522
	2523	240	35.4	125	.283	440	5.5	.053	.0021	.0150	11	.0055	.4	620	2360	6.0	0.58	175	0.12	2523
	2524	240	65	130	.50	260	7	.081	.0016	.0415	18	.0041	.5	830	1560	8.5	0.73	180	0.14	2524
	2525	240	125	135	.93	145	7	.14	.0028	.038	26	.0068	.5	900	3300	7.8	0.73	220	0.14	2525
	2526	240	237	142	1.67	85	7	.22	.0045	.0415	38	.0112	.5	1100	5700	8.5	0.73	230	0.14	2526
	2527	240	355	165	2.15	77	8.5	.27	.0038	.0225	35	.009	.6	1300	15750	3.1	0.92	90	0.18	2527
	2528	240	550	173	3.19	54	8.5	.37	.0051	.0215	42	.0123	.6	1500	25500	3.0	0.92	90	0.18	2528
	2529	240	770	176	4.37	40	10	.48	.0048	.030	38	.0111	.7	1600	25800	3.3	0.92	90	0.18	2529
	2530	240	1170	180	6.53	28	10	.60	.0060	.030	42	.0139	.7	1800	39000	3.9	0.92	105	0.18	2530

1. Type DD1B amplifiers (Bulletin Numbers 2502-2510) operate from a 60 cycle, 1 phase power source, and consist of 1 reactor, 2 saturating rectifiers, and 1 complementary rectifier. (See Note 6.)
2. Type DD3B amplifiers (Bulletin Numbers 2522-2530) operate from a 60 cycle, 3 phase power source, and consist of 3 reactors and 6 saturating rectifiers.
3. Basis of Ratings—
   Reactor—50° C temp. rise above a 40° C ambient
   Rectifier—40° C temp. rise above a 35° C ambient
4. The time constant for any value of resistance in the control circuits can be determined as follows:
   $$TC \text{ (in cycles)} = C_1 \frac{N^2}{R} + C_2$$
5. Additional or special control windings can be supplied. Bulletin Numbers 2502, 2503, 2522, and 2523 require special terminal brackets for more than 3 windings. Other 2500 Series amplifiers require special terminal brackets for more than 4 windings.
6. DD1B amplifiers can be supplied as AD1 (AC output) amplifiers. Current and voltage outputs (RMS) are approximately 1.3 times, and AC power is approximately 1.7 times, DC values shown above.

- **Other Output and Supply Voltages Available.**
- **Standard low input amplifiers (10^{-9} watts) and standard high output amplifiers (4.5×10^6 watts) are also available. Write today for complete information.**

*TRADEMARK

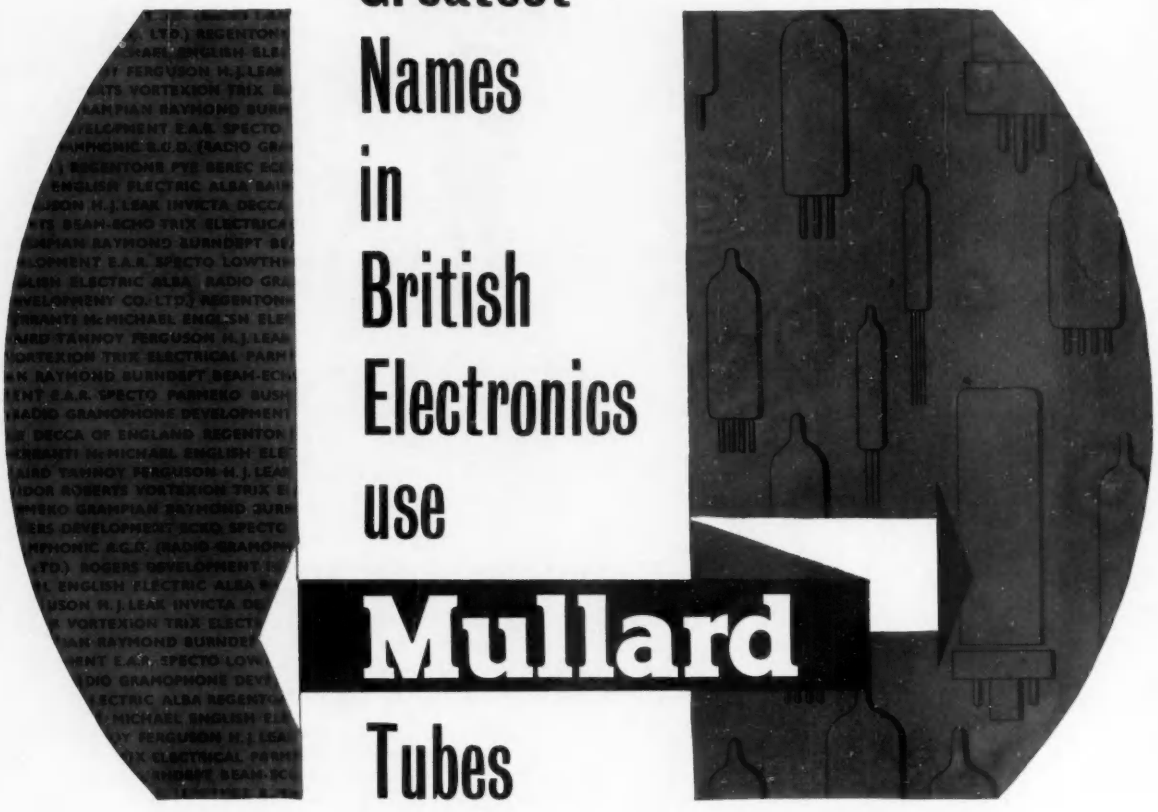
ENGINEERS: There are openings in our expanding program. Write for details.

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VICKERS INCORPORATED a unit of Sperry Rand Corporation

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The Greatest Names in British Electronics use Mullard Tubes



British equipment manufacturers are making a vital contribution to the development of electronics in all fields of application.

Their products are being exported to every corner of the world, earning a universal reputation for advanced techniques and excellent performance.

The majority of these electronic equipment manufacturers consistently use Mullard tubes. This choice is decided upon because they prefer the greater assurance of efficiency and dependability, and because the vast manufacturing resources of the Mullard organisation guarantee ready availability of Mullard tubes wherever they are needed.

Supplies of Mullard tubes for replacement in British equipments are available from the companies mentioned below:—

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International Electronics Corporation,
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81, Spring Street, N.Y. 12.
New York, U.S.A.

In Canada

Rogers Majestic Electronics Limited,
Department LC,
11-9 Brentcliffe Road,
Toronto 17, Ontario, Canada

Mullard

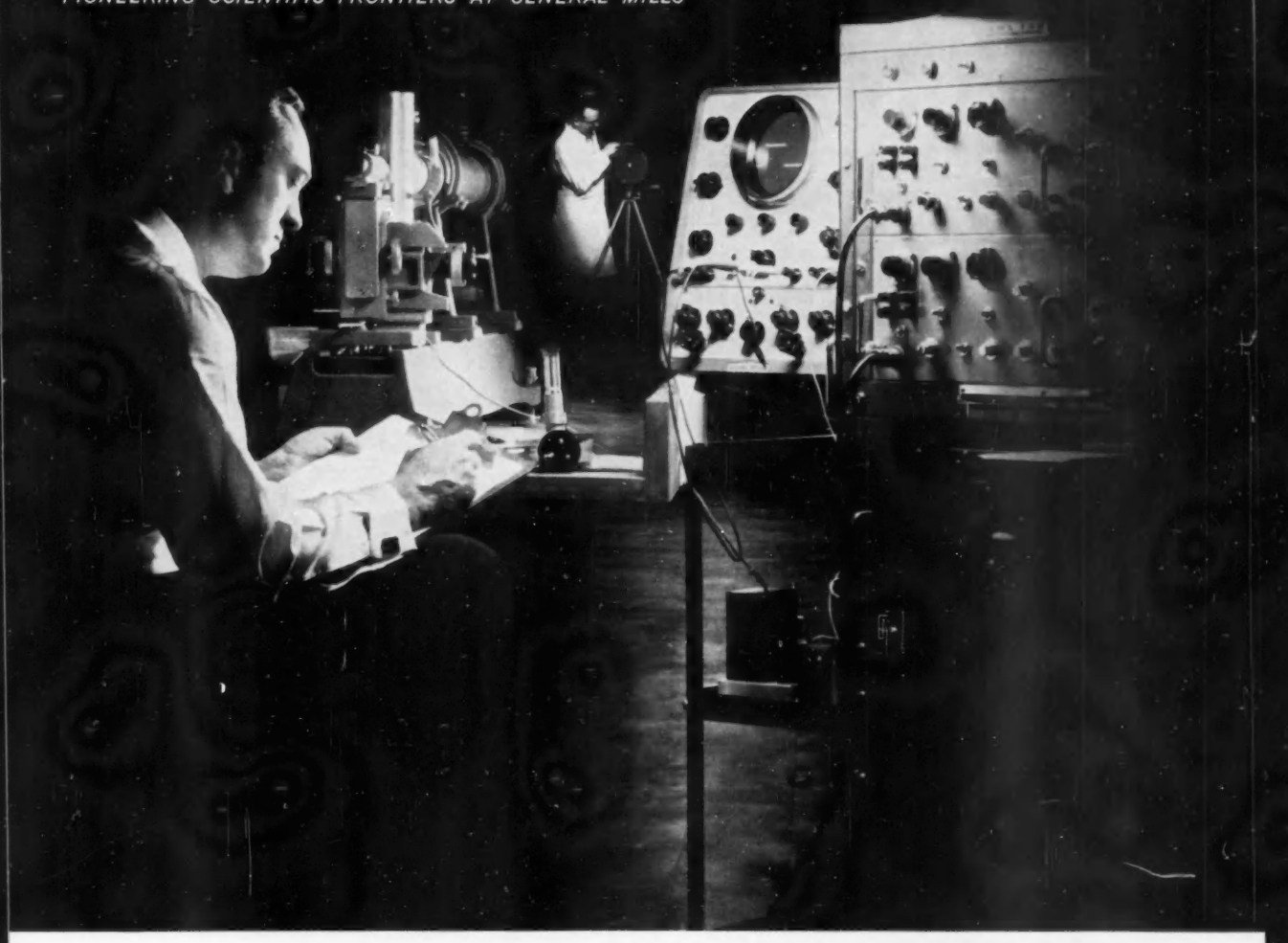
Electronic Tubes — used throughout the world

MULLARD OVERSEAS LTD., MULLARD HOUSE, TORRINGTON PLACE, LONDON, ENGLAND

Mullard is the Trade Mark of Mullard Ltd. and is registered in most of the principal countries of the world

MEV 45

PIONEERING SCIENTIFIC FRONTIERS AT GENERAL MILLS



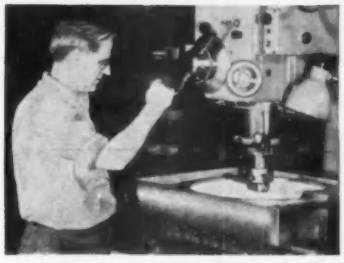
Dr. J. E. Barkley, director of research, takes a reading in the dark tunnel during study of new infrared techniques being conducted by the Mechanical Division of General Mills.

What else can infrared do?

Infrared detection devices have become almost commonplace. These invisible rays are now used in photography and several other industrial and military applications. But the full capabilities of infrared have not yet been determined. Dr. Barkley and his staff, working from an extensive background in current uses of infrared, are researching several possible applications right now.

These studies in basic infrared technology represent but a single phase of General Mills' over-all program of advanced exploration in theoretical and developmental physics, electronics and mechanical design.

Findings in this "research for tomorrow" are being translated regularly into practical applications for industrial and military use today. If you have product or production problems, you can profit from these applications, and from our high-level production facilities.



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Skilled craftsmen, who are as proud of the precision products they produce as they are of the highly specialized machines they use, work with exacting care which comes only from many years of experience. Mass production and on time delivery of electro-mechanical and mechanical devices is routine at General Mills.



Send for Production Facts New booklet shows our facilities, names our customers—introduces you to on time, precision manufacturing. Write Mechanical Division, Dept. CE-3, General Mills, 1620 Central Ave. N. E., Minneapolis, Minn.

MECHANICAL DIVISION

CREATIVE RESEARCH AND DEVELOPMENT + PRECISION ENGINEERING AND PRODUCTION

General Mills

FREQUENCY STANDARDS



*3⅛" high
400 - 1000 cy.

PRECISION FORK UNIT
TYPE 50

Size 1" dia. x 3¾" H. Wght., 4 oz.*

Frequencies: 240 to 1000 cycles
Accuracies:—
Type 50 (±.02% at —65° to 85°C)
Type R50 (±.002% at 15° to 35°C)
Double triode and 5 pigtail parts required
Input, Tube heater voltage and B voltage
Output, approx. 5V into 200,000 ohms

FREQUENCY STANDARD
TYPE 50L



Size 3¾" x 4½" x 5½" High
Weight, 2 lbs.

Frequencies: 50, 60, 75 or 100 cycles
Accuracies:—
Type 50L (±.02% at —65° to 85°C)
Type R50L (±.002% at 15° to 35°C)
Output, 3V into 200,000 ohms
Input, 150 to 300V, B (6V at .6 amps.)



*3½" high
400 to 500 cy.
optional

PRECISION FORK UNIT
TYPE 2003

Size 1½" dia. x 4½" H. Wght. 8 oz.*

Frequencies: 200 to 4000 cycles
Accuracies:—
Type 2003 (±.02% at —65° to 85°C)
Type R2003 (±.002% at 15° to 35°C)
Type W2003 (±.005% at —65° to 85°C)
Double triode and 5 pigtail parts required
Input and output same as Type 50, above

FREQUENCY STANDARD
TYPE 2005



Size, 8" x 8" x 7¼" High
Weight, 14 lbs.

Frequencies: 50 to 400 cycles (Specify)
Accuracy: ±.001% from 20° to 30°C
Output, 10 Watts at 115 Volts
Input, 115V. (50 to 400 cycles)

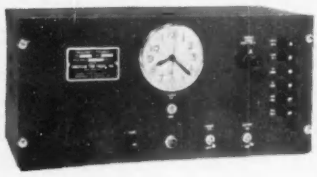


FREQUENCY STANDARD
TYPE 2007T
TRANSISTORIZED

Size 1½" dia. x 4½" H. Wght. 7 ozs.*

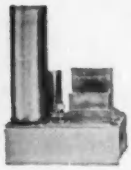
Frequencies: 240 to 1000 cycles
Accuracies:—Same as 2003, above
Type 2007S—Silicon type
Input, 28V.
Output, Multitap, 75 to 100,000 ohms
*3½" in 2007S, 400 to 800 cycles.

FREQUENCY STANDARD
TYPE 2121A



Size
8¾" x 19" panel
Weight, 25 lbs.

Output: 115V
60 cycles, 10 Watt
Accuracy:
±.001% from 20° to 30°C
Input, 115V (50 to 400 cycles)



FREQUENCY STANDARD
TYPE 2001-2

Size 3¾" x 4½" x 6" H., Wght. 26 oz.

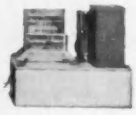
Frequencies: 200 to 3000 cycles
Accuracy: ±.001% at 20° to 30°C
Output: 5V. at 250,000 ohms
Input: Heater voltage, 6.3 - 12 - 28
B voltage, 100 to 300 V., at 5 to 10 ma.

FREQUENCY STANDARD
TYPE 2111C



Size, with cover
10" x 17" x 9" H.
Panel model
10" x 19" x 8¾" H.
Weight, 25 lbs.

Frequencies: 50 to 1000 cycles
Accuracy: (±.002% at 15° to 35°C)
Output: 115V, 75W. Input: 115V, 50 to 75 cycles.



ACCESSORY UNITS
for TYPE 2001-2

L—For low frequencies
multi-vibrator type, 40-200 cy.
D—For low frequencies
counter type, 40-200 cy.
H—For high freqs, up to 20 KC.
M—Power Amplifier, 2W output.
P—Power supply.

This organization makes frequency standards within a range of 30 to 30,000 cycles. They are used extensively by aviation, industry, government departments, armed forces—where maximum accuracy and durability are required.

WHEN REQUESTING INFORMATION
PLEASE SPECIFY TYPE NUMBER

American Time Products, Inc.

580 FIFTH AVENUE, NEW YORK 36, N. Y.

Now...an accomplishment so far reaching it will change the sights of all rectifier users

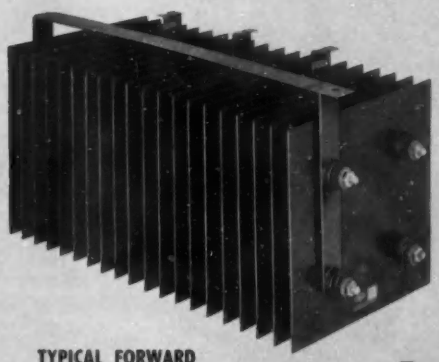
RADIO RECEPTOR'S improved new vacuum process

HCD* PETTI-SEL

**High Current Density*

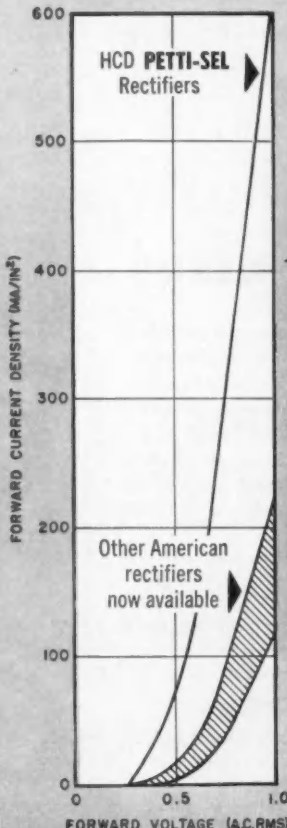
Industrial type SELENIUM RECTIFIERS

Developed by the famous Siemens Organization of West Germany and now manufactured by Radio Receptor Co. in the U. S. A.



- **Estimated life 100,000 hours**
- **Much smaller cell sizes than conventional units of the same ratings**
- **Lower forward voltage drop**
- **Suitable for high temperature applications**

TYPICAL FORWARD CHARACTERISTICS

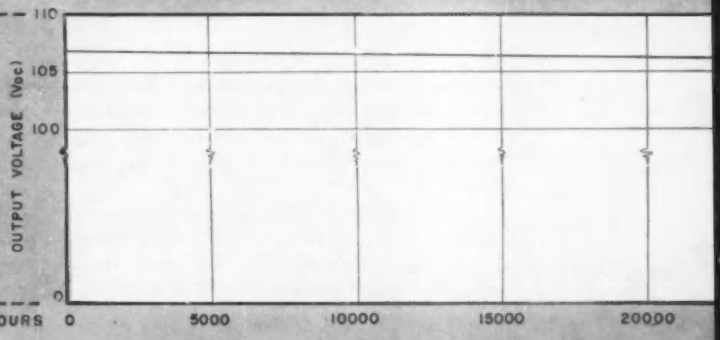


Far smaller in size than other rectifiers of the same current ratings, the new Radio Receptor HCD Petti-Sel units are manufactured under laboratory controlled conditions with fully automatic machinery, assuring new standards of product uniformity.

Field experience extending over several years with these rectifiers indicates an estimated life of 100,000 hours. This is largely attributable to the special process requiring no artificial barrier layer. Low forward voltage drop and low aging rate make the new Petti-Sel Rectifiers applicable to magnetic amplifiers and other control applications.

TYPICAL AGING CHARACTERISTIC

Cell size 4" x 4", single phase bridge (4-5-1-B) operated at 130 volts AC input, 8 amperes DC output current, resistive load, 35° C ambient temperature.



Watch for further announcements of unique developments on these history-making rectifiers. If you would like our new bulletin as soon as it is available, write today to Section C-3R.

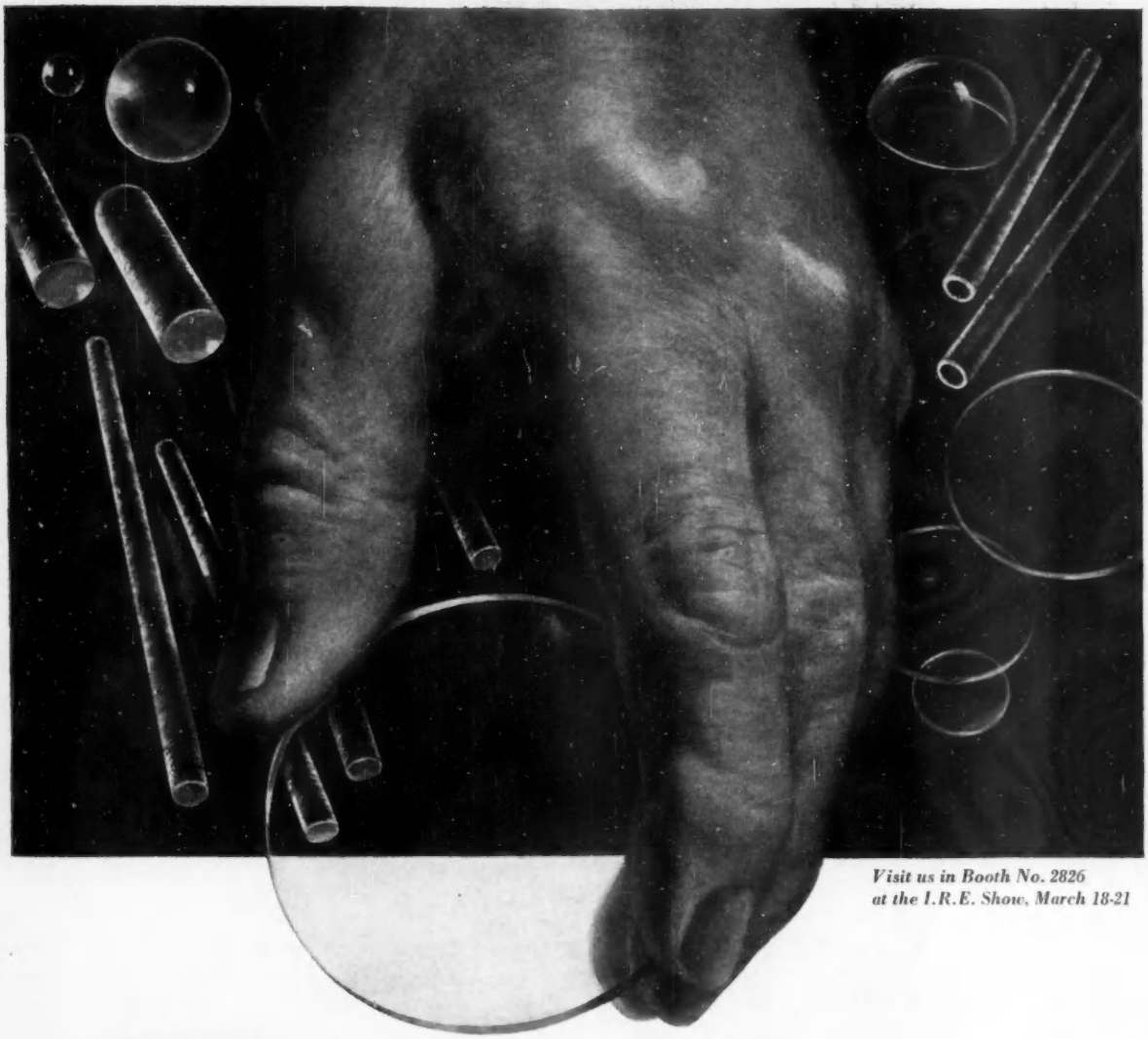
Semiconductor Division

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Radio and Electronic Products Since 1922

240 Wythe Avenue, Brooklyn 11, N. Y. • EVergreen 8-6000

Radio Receptor Products for Industry and Government: Selenium Rectifiers • Germanium Diodes Thermatron Dielectric Heating Generators & Presses • Communications, Radar & Navigation Equipment



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at the I.R.E. Show, March 18-21

LINDE SAPPHIRE...

SHAPED TO YOUR NEEDS

Single-crystal sapphire is produced by LINDE in many shapes for a wide variety of applications. Common shapes include windows, balls, rods, and tubes. Special shapes are supplied to order.

LINDE sapphire is transparent, non-porous, and has excellent ultra-violet and infra-red transmission characteristics. Infra-red transmission is 92% at 3 microns, 50% at 6 microns (1 mm thickness). Typical uses are as windows, spacers, and supports in electronic tubes; for light pipes; and for ultra-violet and infra-red devices. High- and low-temperature seals can be made to metals as well as to glass and ceramics. Inquiries regarding mechanical, optical, thermal, and electrical properties of LINDE sapphire are invited. Write Crystal Products, Dept. CF-3.

Linde Trade-Mark

LINDE AIR PRODUCTS COMPANY

A Division of Union Carbide and Carbon Corporation

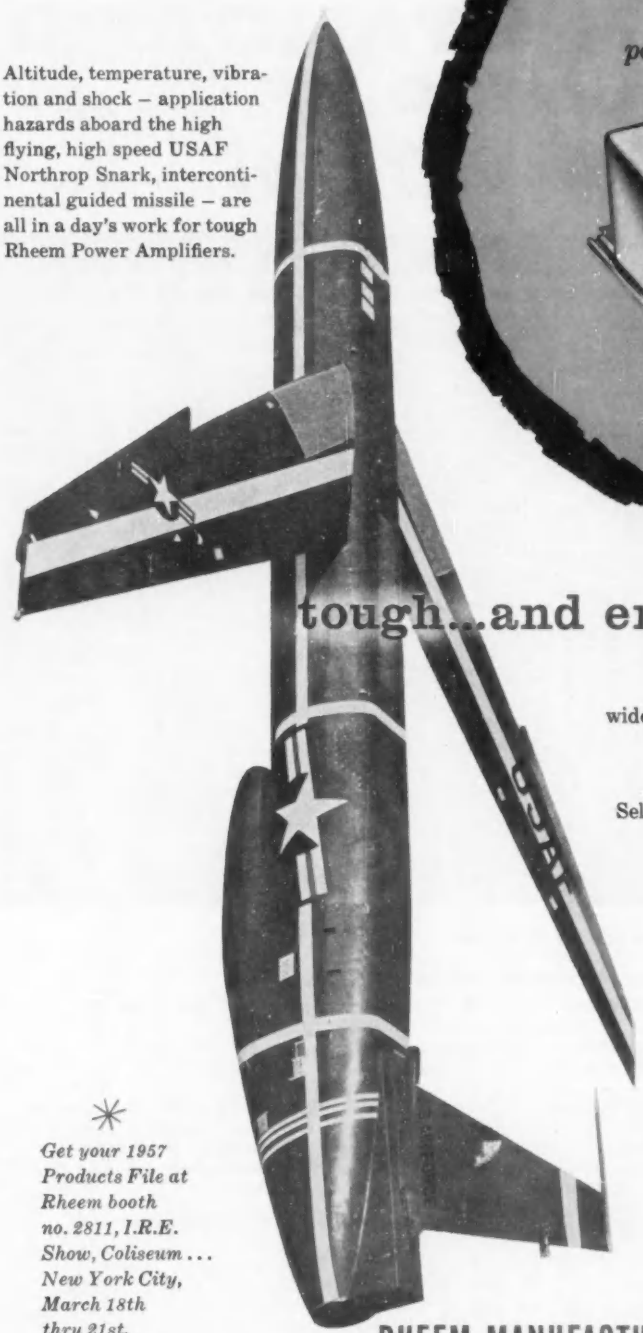
30 East 42nd Street UCC New York 17, New York

In Canada: Linde Air Products Company, Division of Union Carbide Canada Limited, Toronto

The term "Linde" is a registered trade-mark of Union Carbide and Carbon Corporation.

Altitude, temperature, vibration and shock – application hazards aboard the high flying, high speed USAF Northrop Snark, intercontinental guided missile – are all in a day's work for tough Rheem Power Amplifiers.





tough...and engineered to deliver

The REL-09, Miniature RF Power Amplifier, has widespread application in airborne telemetering systems. To ensure reception of high quality signals, step up the power radiated from your airborne equipment. Select the power amplifier which normally exceeds your requirements for vibration, shock, temperature and altitude. Use the Rheem REL-09 for consistent results. Power output—11 watts; Input Drive—1.4 watts. Detailed specification, price and delivery will be furnished promptly on request.

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Get your 1957 Products File at Rheem booth no. 2811, I.R.E. Show, Coliseum . . . New York City, March 18th thru 21st.

5-57

RHEEM MANUFACTURING COMPANY

Electronics Laboratory

7777 INDUSTRY AVENUE • RIVERA, CALIFORNIA

You Can Rely on Rheem

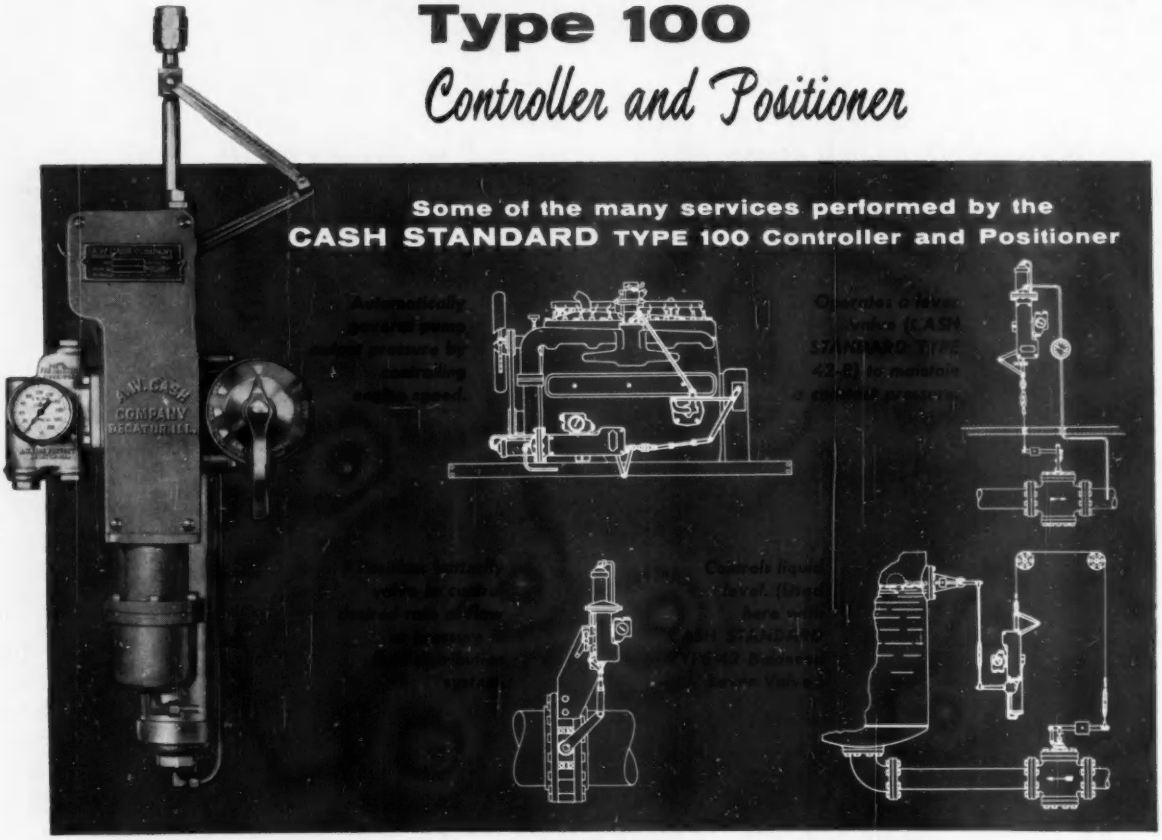
automatic control or positioning problem?

Here's the answer . . . the versatile

CASH STANDARD

Type 100

Controller and Positioner



include this unit in your process system as:

1. A controller with self-contained positioning mechanism.
2. A power positioner actuated by a signal from another controller.

The Type 100 coupled with various types of final control elements will accurately control:

• Pressure • Liquid level • Rate of flow • Other process variables

The Type 100 features: • Feed back type control • Adjustable range • High sensitivity • Linear or curved line characteristics • Reverse or direct action • Optional manual control • Double acting cylinders, 6″ or 12″ stroke, 2″, 2¾″ or 4″ bore for operating pressures up to 125 psi. (Also suitable for larger cylinders in combination with volume booster when higher thrusts are desired.) • Operation by air, oil or clean water.

Available for these signal ranges: • Vacuum • Differential pressure • Pressures up to 600 psig. • Lever motion

WRITE TODAY for complete information, including literature, on this versatile instrument. Dept. F

CASH STANDARD

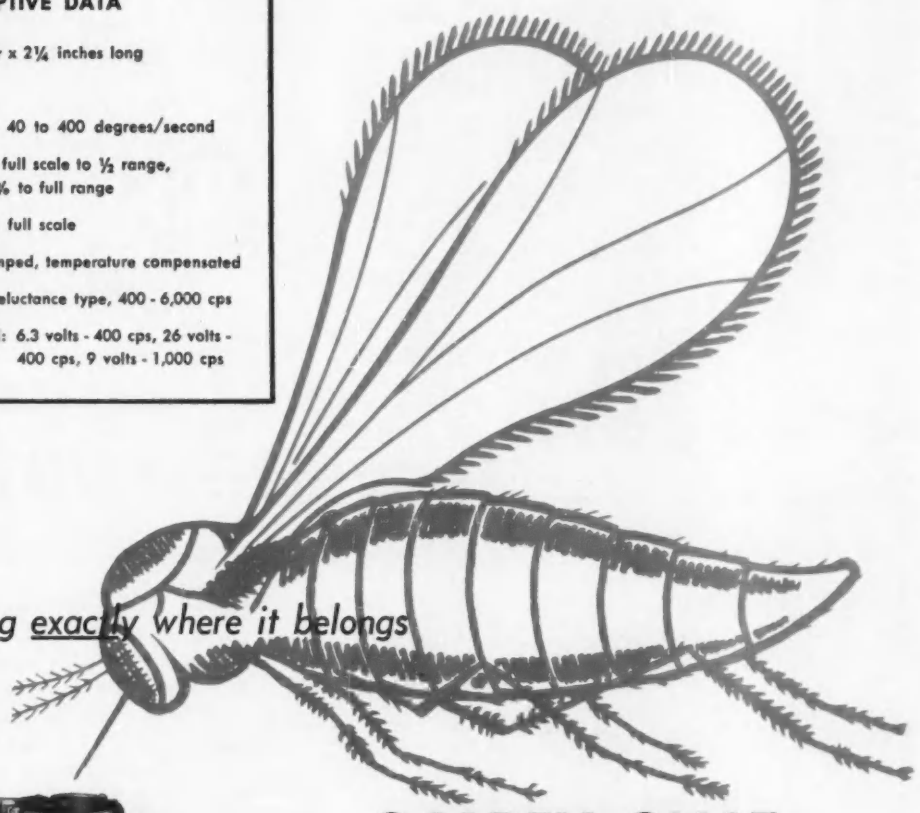
A. W. CASH COMPANY, P. O. Box 551, Decatur, Illinois

Pressure, Hydraulic, Temperature, Process and Combustion Controls

DESCRIPTIVE DATA

- **SIZE:** 1 inch diameter x 2¼ inches long
- **WEIGHT:** 3.8 ozs.
- **FULL SCALE RANGE:** 40 to 400 degrees/second
- **LINEARITY:** 0.1% of full scale to ½ range, within 2% to full range
- **RESOLUTION:** 0.01% full scale
- **DAMPING:** Fluid damped, temperature compensated
- **PICKOFF:** Variable Reluctance type, 400 - 6,000 cps
- **MOTOR EXCITATION:** 6.3 volts - 400 cps, 26 volts - 400 cps, 9 volts - 1,000 cps

Putting the sting exactly where it belongs





Gnat Rate Gyro
Shown actual size

GOLDEN GNAT

Miniature Rate Gyros for Missiles and Aircraft

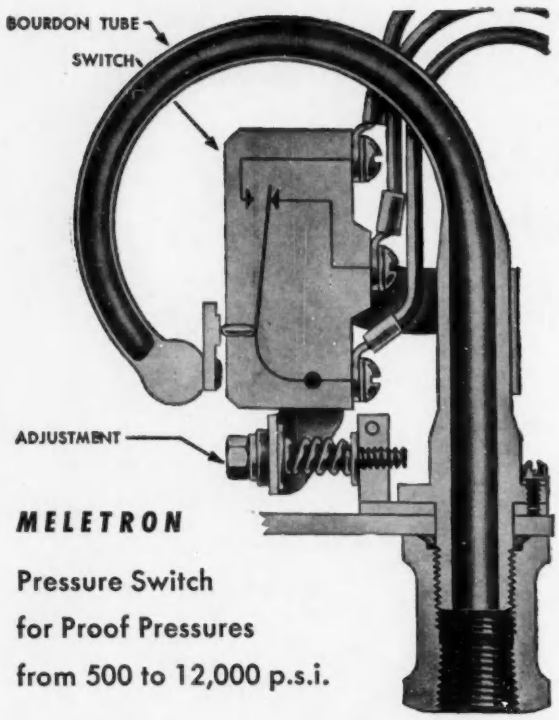
Here is a precision, minature rate gyro. It's tiny . . . measures only 1 inch in diameter and 2¼ inches in length. It's rugged . . . withstands 100G shock and 10G vibration to 2,000 cps. It has a record of proven performance.

Even under the most severe environmental conditions the Golden Gnat will perform as required. To make this possible many unique design details have been incorporated. One such detail is the Gnat's *gold plated* steel housing for improved corrosion resistance and positive hermetic sealing.

Wherever the need exists for high performance miniature rate gyros such as for autopilot stabilization in missiles and aircraft, antenna stabilization and fire control applications, the Golden Gnat is ideally suited. Write for Bulletin GN . . . Minneapolis-Honeywell, Boston Division, Dept. 34, 1400 Soldiers Field Road, Boston 35, Mass.

MINNEAPOLIS **Honeywell** H

BOSTON DIVISION



MELETRON

Pressure Switch
for Proof Pressures
from 500 to 12,000 p.s.i.

Competes on Price
Wins on Accuracy

EXTREMELY ACCURATE

Simplicity of direct acting design plus rugged precision construction make for long, unchanging repeat accuracy.

Note, that we don't use

LINKAGES AND BEARINGS



which, as they wear, cause settings to drift.

IN ANY POSITION

on moving equipment, even under vibration, switch performs with equal efficiency.

Because we don't use

LIQUID SWITCH ELEMENTS

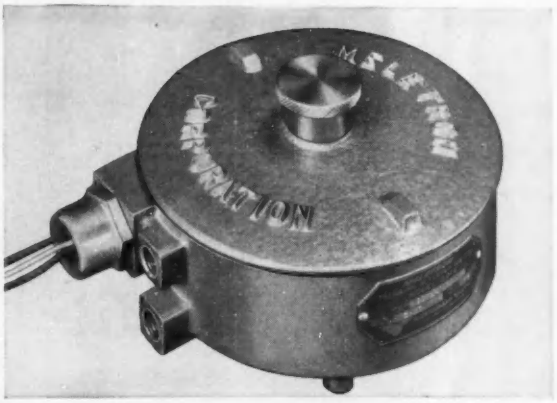


which require that the pressure switch be mounted absolutely vertical, which make it very critical to vibration.

To get complete operating characteristics and specifications ask for bulletins 302 to 382.

BARKSDALE VALVES

PRESSURE SWITCH DIVISION
5125 Alcoa Avenue, Los Angeles 58, California

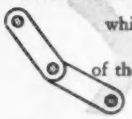
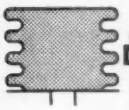


MELETRON

DIFFERENTIAL SWITCH

senses pressure differences from .45 to 45 inches of water

Used in hopper level indicating, on oil burner blower safety control, in instrumentation or similar applications where it is necessary to sense a pressure difference of .45 to 45 inches of water between a variable and a reference pressure. The reference pressure may be as high as 30 P.S.I.

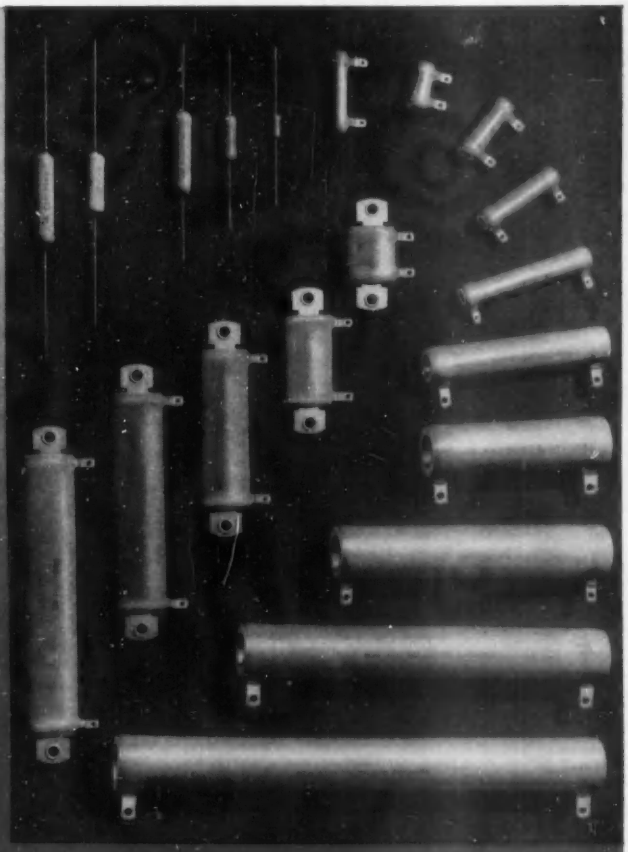
WE BUILD IN	WE DON'T USE
EXTREME ACCURACY and DEPENDABILITY maintained during operating life due to direct acting design	**LINKAGES & BEARINGS**  which as they wear, make the setting of the pressure switch drift.
OPERATION IN ANY POSITION which saves the installation costs encountered in mounting a switch that uses liquid switching elements.	**LIQUID SWITCHING ELEMENTS**  which make the switch difficult to mount and very critical to vibration.
IMMUNITY TO VIBRATION you can mount the switch directly on your vibrating or moving equipment.	**ACCORDION DIAPHRAGMS**  which make the pressure switch sensitive to vibration.

Ask for bulletin 227

BARKSDALE VALVES

PRESSURE SWITCH DIVISION
5125 Alcoa Avenue, Los Angeles 58, California

Now! Vitrohm MIL-R-26C Resistors in all styles!



Famous Ward Leonard Vitrohm® vitreous-enameled resistors are now available in every style to meet all requirements of Military Specification MIL-R-26C including the severe bogeys on moisture resistance, thermal shock, insulation resistance and many other properties.

What's more, this line offers you *all* characteristics—G, V, and the exacting Y—and *all* specification sizes and resistance values—even the highest values using the finest wire (0.00175" dia.) permitted by the spec.

Tab-terminal, axial-lead and stack-mounting types are available in styles and characteristics shown in table.

For complete data on these MIL-R-26C resistors, write us for Bulletin 12. (And incidentally, for Vitrohm resistors to *highest commercial and industrial standards*, get W/L Catalog 15.) Ward Leonard Electric Co., **9** South Street, Mount Vernon, N.Y. In Canada: Ward Leonard of Canada Ltd., Toronto.

ENGINEERING DATA

TYPE	STYLE	AVAILABLE IN CHARACTERISTICS	RESISTANCE RANGE
Stack Mtg.—Tab	RW20 thru 24	G	All values in Spec.
Tab terminal	RW29 thru 47	V, Y* and G	All values in Spec.
Axial lead	RW55 thru 59	V and G	All values in Spec.†

*Characteristic Y applies to styles RW30, 33, 37 and 47 only. Characteristic Y is similar to V but requires high insulation resistance at end of moisture-resistance tests.

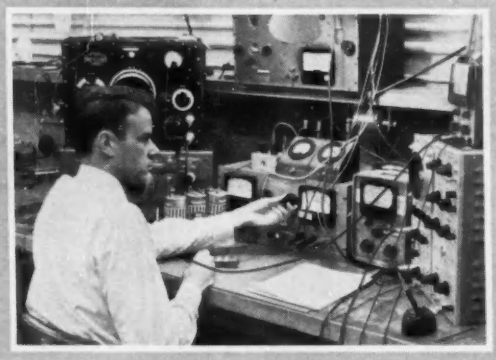
†Maximum values for single-layer-wound resistors with 0.00175" diameter wire.

LIVE BETTER...*Electrically*

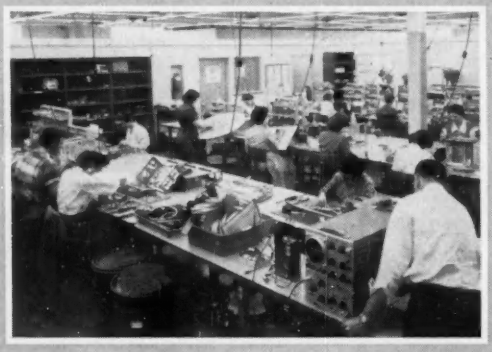
7.7

WARD LEONARD ELECTRIC COMPANY
MOUNT VERNON, NEW YORK

Result-Engineered Controls Since 1892



RESEARCH AND DEVELOPMENT



PILOT LINE PRODUCTION



FINAL ASSEMBLY



TESTING IN SCREEN ROOM

COMMUNICATIONS at Ramo-Wooldridge

Communications activities at The Ramo-Wooldridge Corporation include research, development, and manufacture of advanced types of radio communication systems, ground-reference navigation systems, and electronic countermeasure systems. Major programs are in progress in each of these fields.

New and unusual techniques have been employed to provide systems having a high order of security in the transmission of information, broad flexibility in combating unfavorable signal propagation conditions, and substantially greater information capacity per operating channel.

Some of the techniques used have made possible an increased range for given levels of transmitter power and reliability of communications. Others have provided specific advantages in very long distance communications or in operational situations requiring unique signaling capabilities. Developments in navigation systems have resulted in new equipment that is suitable for the guidance of aircraft at long ranges from their bases.

In the work currently under way, some systems are in the laboratory development stage, some in the flight test stage, some are in production. Several types of systems developed and manufactured by Ramo-Wooldridge are in extensive operational use.

Openings exist for engineers and scientists in these fields of communications activities:

- Systems study and analysis
- Airborne transmitters
- Transistorized video and pulse circuitry
- Airborne receivers
- Reconnaisance systems
- Digital communications systems

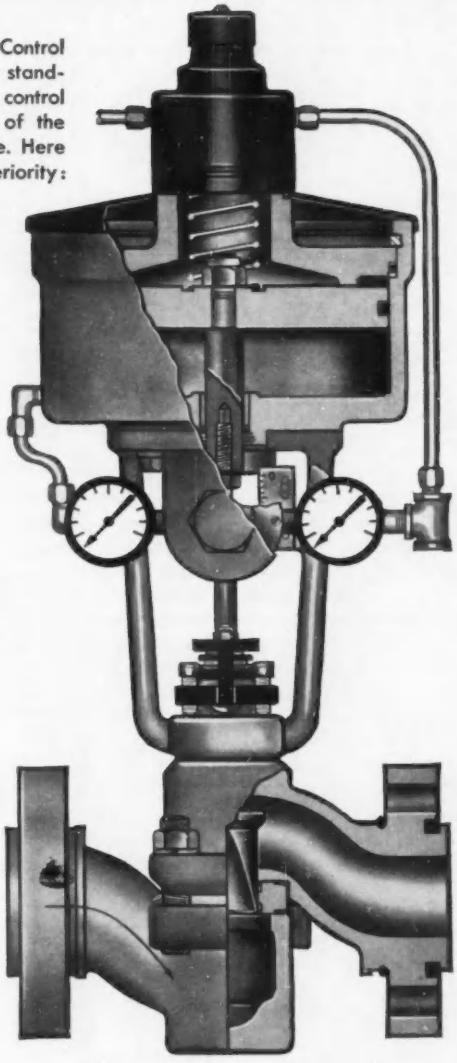
The Ramo-Wooldridge Corporation

5730 ARBOR VITAE STREET • LOS ANGELES 45, CALIFORNIA

LOW FIRST COST
LOWER INSTALLATION COST
LOWEST MAINTENANCE COST

CONOFLOW *Series LB* CONTROL VALVES

Users say Conoflow Series LB Control Valves save more from every standpoint than any other type of control valve. This is based on years of the toughest applications experience. Here are the major points of superiority:



EASY TO INSTALL

Saves manhours. Compact, light yet strong.

INTEGRAL BONNET

Eliminates leakage at joints. Extra deep stuffing box for heavy duty packing. Oversized stem.

RENEWABLE SEAT RING

Quickly replaced with valve still in the line. No threaded insertions to corrode.

INTEGRAL POSITIONER

No exposed moving parts. Convenient zero adjustment while in operation.

PISTON POWERED

Sufficient power to operate under most adverse conditions. No diaphragm to fail.

SINGLE-SEATED DESIGN

Guaranteed tight shut-off over long periods of time despite heavy wear.

STREAMLINED PASSAGEWAY

No cavities for accumulation of deposits to interfere with operation.

00709

WRITE FOR BULLETIN LB-2-A

Cono-Controls®

CONOFLOW CORPORATION
2100 ARCH STREET, PHILADELPHIA 3, PA.

SUBSIDIARY OF WALWORTH

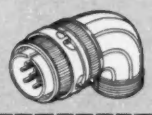
FOREMOST IN FINAL CONTROL ELEMENTS

connect with CANNON PLUGS

for better electrical and electronic equipment

USE for AIRCRAFT and ELECTRONIC INSTRUMENTS

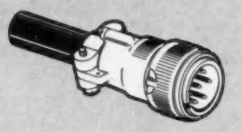
TYPICAL DESIGNS



AN, AN-A, AN-B, AN-C...Conforming to Specification MIL-C-5015C. 15 insert diameters and 260 contact layouts. 6 shell styles, AN3100 to AN3108 with all accessories. Also (AN) F, O(*)AF.

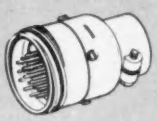


for VIBRATION RESISTANCE and MOISTURE-PROOF applications



AN-E SERIES ... environment resisting. Replaces AN-M. Meets Specification MIL-C-5015C. Resilient inserts. Integral cable clamp. New grounding lugs. Interfacial sealing, improved grommet and new grommet follower.

for GENERAL CIRCUITRY and QUICK DISCONNECT in more rugged applications



K, RK SERIES...**SPECIAL ACME THREAD.** The All-Purpose Series. Conduit and cable clamp entry types. 1 to 82 contacts in 213 different contact layouts. 10-, 15-, 30-, 40-, 60-, 80-, 115-, and 200-amp. silver-plated contacts. High quality phenolic, melamine, and formica insulators. Cadmium-plated aluminum alloy shells.



for UNIT-PLUG-IN applications...



DP, DPB, DPD, DPD2, DPD2R, DPJ, AND DPS SERIES ... Rack/panel/chassis. With and without shells; coaxial and high voltage contacts. Permit quick disconnect, interchange, replacement, testing and inspection of assemblies and sub-assemblies.

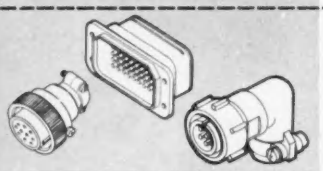
for AUDIO and LOW LEVEL circuits



P, XLR, XL, XK, O, UA, BRS SERIES... many shell styles and insert layouts. Straight and angle 90° plugs. Latch-lock types. Wall-mounting, panel, locknut mounting, and adapter receptacles, single- and two-gang. 10- to 30-amp. contacts, coaxials. UA Series features 3 gold-plated contacts.

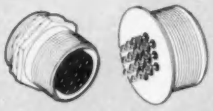


for RADIO and SUB-MINIATURE applications



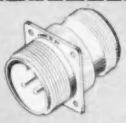
D, MC, DPA, DPX, AND K MINIATURES... miniatures and sub-miniatures designed for amplifiers, miniature indicators, computer circuits, telemetering equipment, small pre-amps, and general instrumentation where space is limited and current requirements are generally not over 5 amperes. Variety of shell styles, junction shell, and insert arrangements. 3 to 50 contacts, plus coaxials.

for HERMETICALLY SEALED applications



GS (AN TYPE), KH, RKH, DAH, BFH, TBFH, DBH, KH30... with steel shells and contacts to withstand high pressures from within or without. Insulation is a glass material, fused under high temperature to shell and contacts, thus forming a hermetic seal.

for HIGH TEMPERATURE and firewall applications



AN-K, AN-"FW," AND CANNON K-"FW" STEEL SHELL CONNECTORS... Open flame protection offered in the greatest variety of this type of connector. Wall- or box-mounting receptacles. Straight or angle 90° plugs. Crimp-type contacts. Inserts of glass-filled materials.

Send for AR Condensed Catalog containing illustrations and technical information on all principal series of connectors in the extensive Cannon Line.

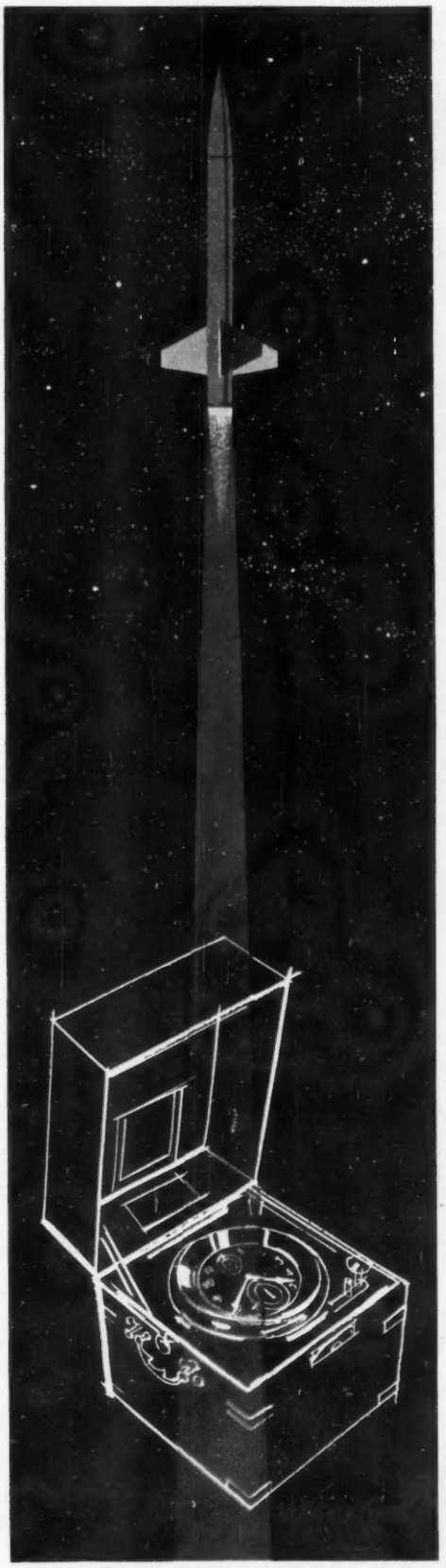


CANNON ELECTRIC COMPANY, 3208 Humboldt St., Los Angeles 31, California. Factories in Los Angeles, Salem, Mass., Toronto, Can., London, Eng., Melbourne, Austl. Manufacturing licensees Paris, Tokyo. Representatives and distributors in all principal cities.

please refer to Dept. 422

CANNON ELECTRIC

Since 1915



AC's NEW INERTIAL GUIDANCE SYSTEM—

the achiever...

more intricate than a chronometer... infinitely more accurate!

Even a chronometer need not be engineered down to the millionths-inch tolerances held in the AC Achiever—new inertial guidance system now in development at AC's Milwaukee plant.

Unbelievable accuracy makes the Achiever one of the most important new guidance systems in America's arsenal of defense. What's more, this remarkable new device cannot be diverted from its course by radio or radar jamming or any other similar method.

All this is thanks to a new concept in gyroscopic control and inertial guidance with a new-type gyro stabilization of uncanny precision, a phase of AC's current work as a prime contractor to the Air Force.

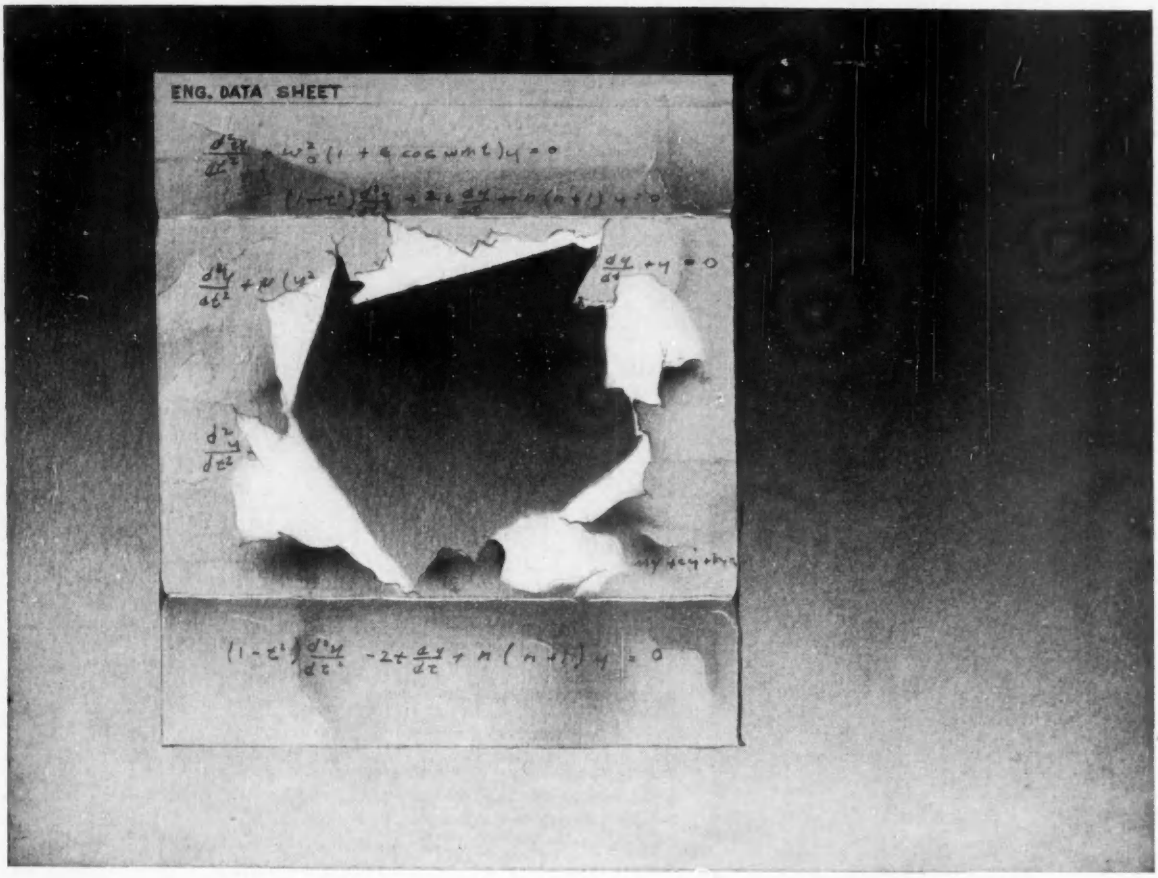
AC's engineers are eminently qualified to take the most complex problems from the "dream stage" straight through final production. Because of this competence, they know that, for them, the future represents "Opportunities Unlimited"!

GM GENERAL MOTORS

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THE ELECTRONICS DIVISION OF GENERAL MOTORS

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Break Through The PROBLEM Barrier



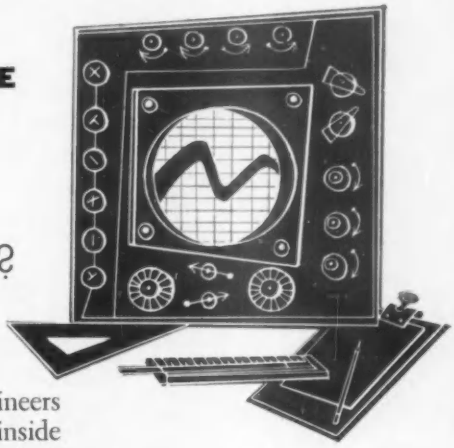
Making it possible for Engineers to break through the problem barrier is our most important project. Since our Company's inception, constant attention to the human engineering factor has brought about such advantages as High Speed Servos, Automatic Extended Readout with push-button control, Problem Checks, Electronic Multipliers, Servo Voltmeters, Resolvers and Function Generators, etc. Our standard production has the further advantage of actual time in the field before being announced as "new." Just one more reason why you can always look to PACE for Progress in Analog Computing Systems, for reliability, stability and overall economy. For details, write Electronic Associates, Inc., Dept. CE-3, Long Branch, New Jersey.

ELECTRONIC ASSOCIATES Incorporated

EAI SETS THE PACE

P PRECISION A ANALOG C COMPUTING E EQUIPMENT

LONG BRANCH, NEW JERSEY



What Test Equipment Fills the Control Engineer's Toolkit?

Like the country doctor of yesteryear, early control engineers roved the field with all of their tools rattling around inside one small black bag—but instead of a tongue-depresser, in their breast pocket they toted a slide rule. Today, however, it takes a station wagon to lug all the useful test equipment of the practicing control engineer.

From black bag to station wagon

What are these tools for the diagnosis, analysis, and cure of control-system ailments? Where and how often does the control engineer use them? And what characteristics does he look for?

An epic attempt to bring useful answers to these questions was made last summer when CONTROL ENGINEERING's research staff surveyed 3,400 subscribers in all fields of instrumentation and control. By September 699 detailed answers to the four-page questionnaire had come in. This goodly response (20.56%) was then punched into cards and tabulated.

As a logical opener the survey queried, "Do you use or specify test instruments in your work?" Nearly all assented (659 out of the 699). Those saying "yes" were then asked what percentage of their test equipment was either A) commercially available general-purpose units, or B) normally unavailable special-purpose black boxes. The answers were heavily weighted toward general-purpose test units: less than a third indicated that special rigs comprised more than one-third of their equipment.

The next question attempted to classify the test equipment into three use-areas: 1) R&D, test, and environmental labs; 2) in-process, final inspection, and quality control; 3) trouble-shooting and maintenance. In the answers it was apparent that roughly one-half of the equipment was used in R&D work, one-fourth in the plant, and the remainder for maintenance.

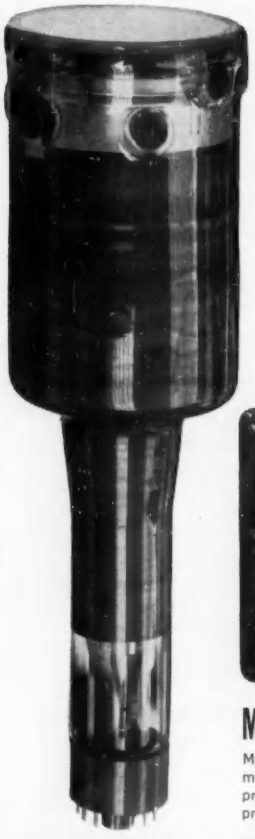
R&D leads the way in use

What specific test units are used in the work above? To guide respondents, a list of 34 different testing items—ranging from gauss meters through shake tables to Geiger counters—was assembled. The ten units mentioned most frequently by the 659 respondents are listed below:

Vacuum-tube voltmeters	—575
Oscilloscopes	—548
Power supplies	—499
Multimeters	—474
Signal generators	—463
Frequency meters	—449
Amplifiers	—440
RLC bridges	—433
Decade (RLC) boxes	—428
Electronic counters	—396

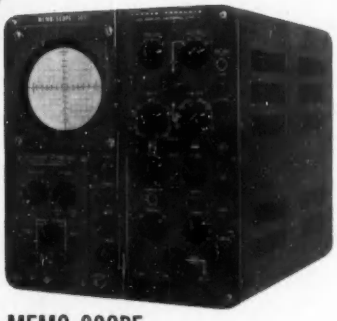
While this rating testifies strongly to the utility of well-known

Three unusual direct-display storage tubes by Hughes



MEMOTRON

FEATURES: bright display . . . constant and uniform intensity of presentation . . . no perceptible transient decay . . . simplifies photography. APPLICATIONS: transient analysis . . . spectrum analysis . . . direct comparison of wave forms. SPECIFICATIONS: 100,000 inches/sec. writing speed . . . stores traces until intentionally erased . . . erasure triggered by push-button, or programmed voltage . . . electrostatic focusing and deflection.



MEMO-SCOPE

Model 104, incorporating MEMOTRON, is a new memory oscilloscope with 5 optional preamplifiers to satisfy the most critical production, test and laboratory requirements.



TONOTRON

FEATURES: half-tone presentation . . . excellent grey scale . . . controllable decay rate . . . compact design. APPLICATIONS: closed circuit TV . . . instrumentation . . . P.P.I. . . . narrow band, slow scan TV. SPECIFICATIONS: 1,000 foot-lamberts brightness at 10 kv . . . electrostatic focusing . . . magnetic deflection . . . . 60 lines per inch resolution . . . writing speed of 150,000 inches/sec.



TYPOTRON

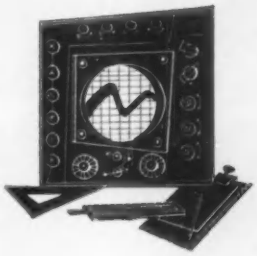
FEATURES: high brightness . . . permanent display until intentionally erased . . . rapid display of printed data . . . 63 character matrix. APPLICATIONS: digital computers . . . teletype reception . . . wherever printed data must be displayed rapidly for use by human operator. SPECIFICATIONS: writes up to 25,000 characters/sec. . . . permanent storage until erased . . . almost instantaneous erasure . . . electrostatic focusing and deflection.

See demonstrations of these tubes and MEMO-SCOPE *at the I.R.E. Show, booths 2801, 2803, 2805, Second Floor. For additional information write to:*

HUGHES PRODUCTS • ELECTRON TUBES
International Airport Station, Los Angeles 45, California

HUGHES PRODUCTS

© 1957, HUGHES AIRCRAFT COMPANY



broad-use test units, it does not reveal those peculiar passions of the control engineer. This is left to the lesser-mentioned items. Take the need for permanent test records: 333 use recording oscillographs, 215 tape recorders, 206 X-Y plotters. Special analyzing equipment also came in strong: 168 use servo analyzers and spectrum analyzers, 338 run strobe lights, 264 have distortion analyzers. Other noteworthy items: vibration testers, favored by 302; cold, humidity, and altitude chambers, each used by more than 200.

Recorders make strong inroads

A later question in the survey sought to determine which test units are used most frequently. The respondent was asked to list the five items he employed the most. The "ratings" from 546 answers were then listed in order of first-place mentions, with their subsequent placings tabulated. Notice how in each case, with the exception of transducers, there is a straight correlation between the order the items appear in and the column in which they lead in mentions.

	Number of Mentions per Place				
Item	1st	2nd	3rd	4th	5th
Oscilloscopes	**177**	121	61	48	28
Vacuum-tube voltmeters	121	**140**	71	42	35
Multimeters	76	48	**83**	34	39
Signal generators	22	38	52	**63**	38
Transducers	17	21	18	11	21

Some are used like tuxedos

While again confirming the popularity of basic, broad-use equipment, the answers also indicate that some near-to-hand items, such as power supplies and decade boxes, are not kept very busy.

Another series of questions referred to operating aspects of equipment. First, what nonelectrical parameters were being measured and what was the preferred mode of signal conversion (voltage, current, or frequency)? The tabulation below reveals the more frequently measured parameters and an overwhelming preference for voltage conversion (577 respondents answering):

PARAMETER	Voltage	Current	Frequency
Shaft position	349	61	67
Temperature	317	161	24
Pressure	296	84	42
Velocity	275	50	102
Flow	246	56	72
Acceleration	238	45	49
Displacement	235	68	60
Strain	194	57	23
Vibration	182	36	81
Direction	170	37	21
Level	160	50	16
Altitude	145	32	19
Tension	118	35	18
Shock	95	25	25

Granted the universality of the shaft position parameter (so

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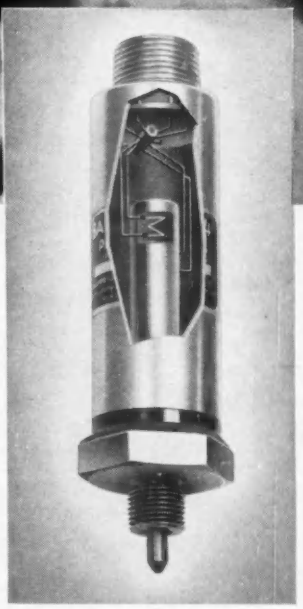
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important in servo and analog systems), it is still interesting to see how the old "war horses" of temperature, pressure, and flow dominate the measurements—a sure sign that so-called process variables prevail, no matter what the field or application is. This is verified by an analysis of those responding to the survey: more than half were involved with control in military and machine systems. Another interesting sign is the growing use of frequency as a measuring conversion technique. In most cases this would indicate direct digital readout.

The "war horses" hold sway

Two of the most widely-used test units were selected (oscilloscopes and vacuum-tube voltmeters) and the users were asked to rate their most important design characteristics.

OSCILLOSCOPE DESIGN RATINGS

(out of 599 respondents)

high sensitivity (better than 10 mv/in. vert. defl.)	343
built-in calibrator	330
wide bandwidth (above 100 kc)	234
very slow sweep speeds (below 1 sec/cm)	192
fast sweep speeds (faster than 1 microsec/cm)	157

VT VOLTMETER DESIGN RATINGS

(out of 593 respondents)

high input impedance (1 mc or better)	500
high sensitivity (10 mv full-scale or better)	412
high accuracy (1% full-scale or better)	344
high frequency response (1 mc or above)	121
peak reading scale	75

The fact that these design characteristics were deemed most important points up some unique things about control field testing. Most apparent is the emphasis on sensitivity—a sure sign that the systems under test are relatively complex and have very low level signals. In the 'scope, the need for a wide bandwidth suggests the importance of frequency response techniques. And emphasis on varying sweep speeds points to the inroads of analog and digital computer techniques.

Sensitivity rules the roost

To round out the picture of desired characteristics, the users were next asked to consider the overall test equipment field:

FIVE MOST FAVORED GENERAL CHARACTERISTICS

(out of 642 respondents)

simplicity of operation	465
rugged construction	317
all control knobs readily accessible	245
self-checking facility	227
environment resistant	168

One note of special interest. The characteristic "transistorized circuits" was favored by only nine people. This leads

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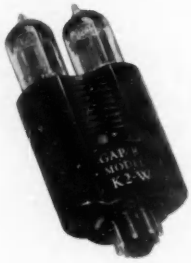
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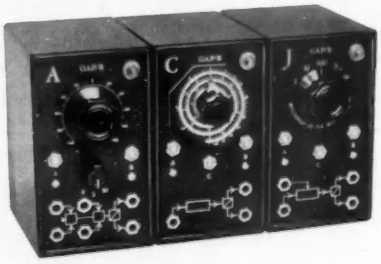
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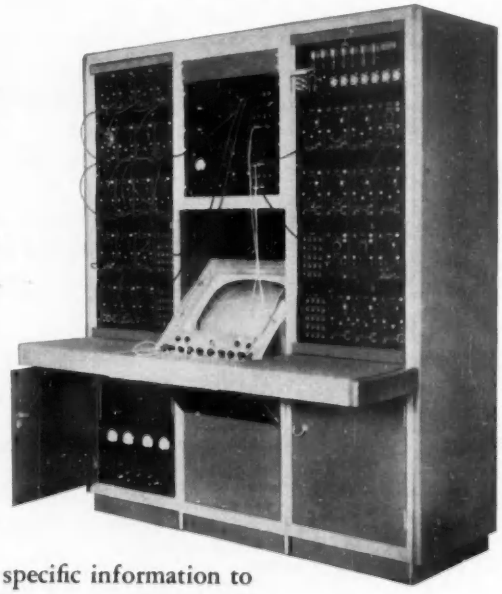


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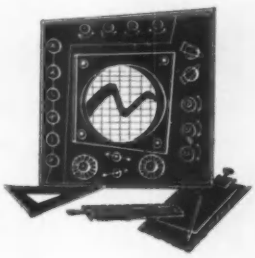
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to the conclusion (supported by respondents' comments) that transistors are still considered too costly and unreliable in test equipment.

Several other questions in the survey were directed toward equipment use and function. Below is a round-up of the answers:

▶ the importance of digital readout: first, to minimize operator error; second, for accuracy, and last, convenience.

▶ the users were rather evenly divided on whether a combination of digital and meter presentation is desirable.

▶ the users were evenly divided on the usefulness of instruction manuals provided with the equipment.

▶ 548 out of 629 reported that their company maintained and repaired its own test equipment.

▶ 534 out of 633 indicated that their company also calibrated its own test equipment.

Another skill for the control engineer

The preponderance of company maintenance and calibration facilities revealed in the last two answers is surprising, considering the complexity of the test units involved and the expensive nature of their maintenance. This suggests that control engineers place a high premium on the availability of working test equipment. And that they retain the special necessary skills that keep this equipment in operation.

Another clue to the importance control engineers attach to test equipment came in answer to the survey question, "Do you design, specify, or work with control systems that utilize test equipment as system components?" Of the 637 answers, 393 revealed that test units could also be a permanent part of a working control system. Small wonder that facilities are available in the plant to service such equipment!

Test a part of working systems

To round out the survey, a group of queries was made about the actual or planned investment in test equipment by each user's company. Below is the tabulation of actual dollars invested during the past year:

(out of 372 respondents)

$1–$1,000	60
$1,001–$10,000	154
$10,001–$50,000	88
$50,001–$100,000	38
$100,001–$500,000	19
$500,001–$1,000,000	3
Over $1,000,000	10

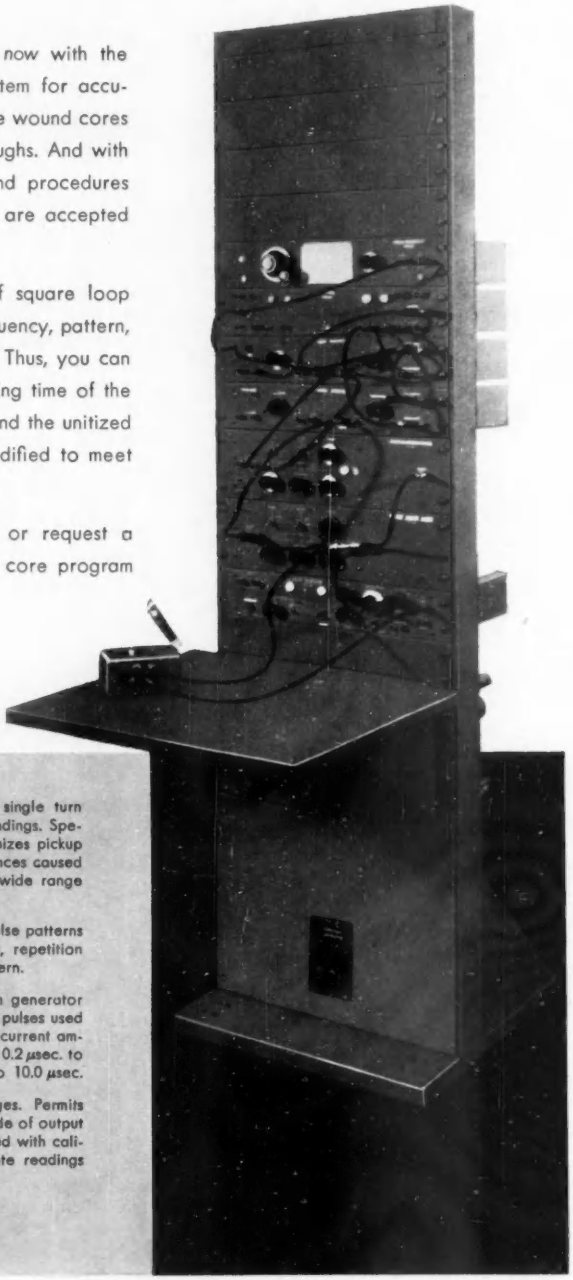
With respect to future test equipment outlays, 266 out of 551 indicated that their companies will spend more during the next 12 months, 193 that their companies will spend at the same level, and only 92 that they will spend less. Incidentally, the total expenditures reported by the respondents for the past 12 months amounted to $30,131,810. Extrapolate that over the complete control field and the amount of money earmarked for control system tests becomes very impressive indeed.

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Control ENGINEERING MARCH 1957

DONALD PIERCE CAMPBELL

The control engineering field suffered an irreplaceable loss with the untimely death of Donald P. Campbell on Jan. 15, 1957.

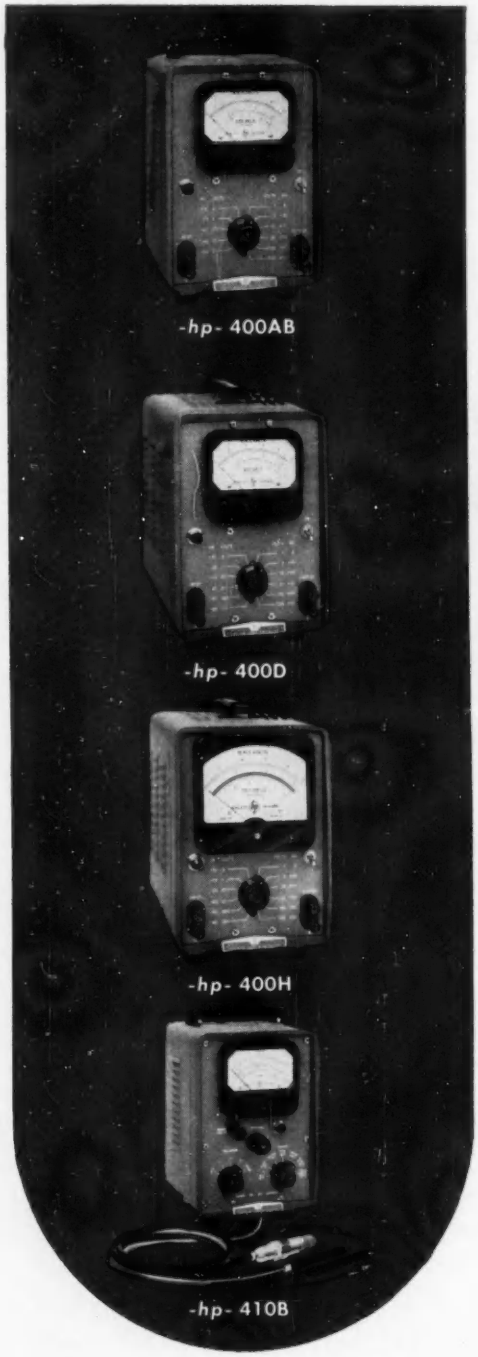
Only 38 when struck down by a heart attack, Don had yet to approach the zenith of a career which saw him, at 22, creating and teaching the first courses in the new science of servomechanisms, at 30, probing the dynamics of chemical processes, and, at 37, consulting all over the world in the application of systems engineering. Last year he left MIT, where he had been a member of the Electrical Engineering Dept. since 1940, to devote all his time to the large number of incredibly varied feedback control projects that he had activated here and abroad.

Don Campbell, more than any man we know, typified the wide-ranging, creative control engineer. He was infinitely curious, eternally questioning. Often when a student or an engineer would come up with a good solution to a problem, Don would startle the innovator with the query, "Isn't there a better way?" And then would go on to suggest new basic approaches — unorthodox, true, but always deeply rooted in the fundamentals of dynamics and feedback control. He encouraged others – and this magazine was often among them—to be friendly to the "crackpot" idea . . . to explore the unknown and to be willing to make mistakes in its pursuit. He lived the classic rules of our game: try . . . evaluate . . . try again.

Donald Pierce Campbell was a scientist, an engineer, an artist, a philosopher, and an explorer of people and places. And above all, he was a teacher: no matter where he went he was driven – by his innate enthusiasm and superb knowledge of the scope of our budding science – to teach. We count our lucky stars that our magazine was often one of his stopping places.

THE EDITORS

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Can You Take Advantage of the CYCLIC BINARY-DECIMAL CODE?

THE GIST: Among the common digital codes are the scalar (or normal) binary code, the reflected binary (or Gray) code, and the binary-decimal code. The last two represent attempts to overcome difficulties encountered with the scalar binary code. One of these difficulties has to do with the large errors that can occur during the time the reading slit of a disc coded in scalar binary is moving from one coded number to the next, since several code digits can change at once and part of each number may be read. The complicated decoding matrices necessary to convert scalar binary into decimal present another problem, while the difficulty of recognizing register contents in terms of their decimal equivalents, once they have been extracted from the computer by the operator for checking purposes, represents still a third.

The reflected binary code solves the reading-accuracy problem, since only one code digit changes in going from one decimal number to the next, but this code is more difficult than scalar binary to decode, and is just as difficult for the operator to recognize. In the binary-decimal code, where each decimal digit is represented individually by a scalar binary code, decoding and the visual interpretation into decimal form are easy, but difficulties are still encountered in reading accuracy because of the change of multiple digits.

One solution to the whole problem is to combine the reflected and the binary-decimal codes into a cyclic binary-decimal code that is easy to decode and interpret and has high reading accuracy. Author Glixon shows how to form such a code, and discusses code-modification and decoding networks.

HARRY R. GLIXON, Consolidated Avionics Corp.

Before discussing the cyclic binary-decimal code, it is best to briefly review the reflected binary and binary-decimal codes. In the reflected binary code, one, and only one, code bit changes for an equivalent change of "one" in the translated arabic numbers. Under these circumstances the maximum readout error is likewise "one". In addition, the code is cyclic; that is, it is possible to return to the zero-code designation by changing only one code bit at any of the binary numbers: 1 to 0 instead of 2, 3 to 0 instead of 4, 7 to 0 instead of 8, 15 to 0 instead of 16, etc. (see Table I). This is an advantage when the code is displayed on a circular disc, since a binary number of digits can be arranged so that there is never more than one code bit change around the circle. Decoding involves first translating into scalar binary and then into arabic decimal.

The binary-decimal system is an approach to reducing decoding difficulties. A decimal decade can be represented in an ordered or arbitrary way by

TABLE I – COMPARING DIGITAL CODES

Arabic decimal	Scalar binary	Reflected binary	Cyclic binary-decimal WXYZ
0	0000	0000	0000
1	0001	0001	0001
2	0010	0011	0011
3	0011	0010	0010
4	0100	0110	0110
5	0101	0111	0111
6	0110	0101	0101
7	0111	0100	0100
8	1000	1100	1100
9	1001	1101	1000
10	1010	1111	11000
11	1011	1110	11001
12	1100	1010	11011
13	1101	1011	11010
14	1110	1001	11110
15	1111	1000	11111
16	10000	11000	11101
17	10001	11001	11100
18	10010	11011	10100
19	10011	11010	10000
20	10100	11110	110000
100	1100100	1010110	11000000
1023	1111111111	1000000000	1100000110010

TABLE II — RECORDED AND MODIFIED CODES

Actual Code as Recorded							
Cyclic binary-decimal code—	0101	0010	1010	1010	1101	1000	0000
Equivalent arabic number—	6	3	3	3	6	9	9
Cyclic binary-decimal code—	0101	0010	1010	1010	1100	1000	0000
Equivalent arabic number—	6	3	3	3	7	0	0
Modified Code Required for Decoding							
Modified Cyclic binary-decimal code—	0101	0010	0010	0010	0101	1000	1000
Equivalent arabic number—	6	3	3	3	6	9	9
Modified Cyclic binary-decimal code—	0101	0010	0010	0010	0100	0000	0000
Equivalent arabic number—	6	3	3	3	7	0	0

any ten of the 16 possible ways in which four two-state values can be combined, four at a time. This combination of two-state values, known as a decimal code, permits easy translation and visual interpretation. However, the binary-decimal code is not as efficient as scalar binary. It requires four two-state values to represent a decade (0 to 9); the same four two-state values represent 0 to 15 in scalar binary.

Cyclic binary-decimal code

When the binary-decimal code is such that only one of the two-state values changes for each corresponding change of one in the translated arabic decimal enumeration, it is known as the cyclic binary-decimal code. Many such codes can be used to represent the numbers zero through nine. The difficulty arises in representing the number ten and all other decade numbers. If the code designations for zero to nine are unique and the code is cyclic, it follows that two changes of the two-value states must occur in going from nine to ten. This is because the "tens" decade changes from the code designation of zero to one, while the "units" decade changes from nine to zero. This change of two code bits is contrary to the basic principle of a cyclic code where, by definition, only a single code bit may change for any increase of one in the arabic decimal system.

Since it requires a two-code bit change between nine and ten and a similar change between 19 and 20, the cyclic decimal code could be designed about twenty, relying on information from two decades to translate a number, Table I. The four two-state values have been designated as W, X, Y, and Z, to which subnumbers are added to designate decades above zero. The only difference between the code designations for zero to nine in the two decades shown (0 to 9 and 10 to 19) is that the first two-state value, W, is reversed when the tens decade is one (from 10 to 19). Since the code is repetitive after 20, the decoding translation can be made unique by first determining if the arabic value of the preceding decade (proceeding from left to right) is odd or even (zero considered even) and then modifying the W value to reverse its state if the preceding decade is odd. In this manner, the code presented to the decoding system will always have a unique code designation for every arabic number—no ambiguities occur and decoding is possible. Thus, the cyclic binary-decimal code remains cyclic but requires a code modification before decoding is possible. An example will clarify things.

The first (left-hand) digit of any arabic decimal number greater than one has zeros implied in all preceding decades. For example, 000006333699 is the same as 6333699. Therefore, the first (left-hand) code designation requires no reversal of its W two-state value since its preceding decade is zero. Consider the numbers 6333699 and 6333700. The top portion of Table II shows the actual recorded code for these numbers, while the lower portion shows the code modifications necessary to evaluate the decimal number for each decade. The first decade can be decoded directly by the code designation where 0101 corresponds to six (see Table I). The second decade requires no modification—its preceding decade is also even (six) so that 0010 is decoded as three. Since three is an odd number, a reversal is required in the next decade. In this case the code designation in the upper portion of Table II, 1010, is changed by reversing the W value so that the modified code in the lower portion of table becomes 0010 and can be decoded as three. (Note that before modification this code for three corresponds to the code for 13 in Table I.) All other code designations are similarly corrected.

All arabic numbers now have unique code designations and no ambiguity can occur in decoding. The next higher arabic number in the upper portion of Table II shows the cyclic nature of the code. The only bit change takes place in the Z location of the code designation for the arabic number six. By becoming familiar with the code designations for the numbers zero to nine in the first decade, it is easy to visually evaluate even large coded numbers.

Modification circuitry

It has been shown that two distinct code designations are used to represent the arabic numbers

from zero to nine. These codes differ from each other only in that the two-state values W are reversed. Now, to decode the binary-decimal code it is necessary that a unique code be presented to the decoder for converting. This means that one of the two code designations for zero through nine must be chosen as the unique code for decoding, and the other code must be modified. Since the code with the zero or even coefficient for the preceding decade produces a simpler modification circuit, it is chosen as the standard code, to which the other is modified. This corresponds to the procedure followed in Table II.

The modification circuit does not correct the entire code simultaneously, but rather sequentially as shown in Figure 1. The coefficient of the highest-order term is initially translated; then the succeeding decades (left to right) are modified in their turn.

Figures 2 and 3 show circuits that modify the codes so that they are identical when presented to the decoder. In Figure 2 the odd output from the previous decade's decoder is isolated and used to energize a reversing relay. The modifying relay (or other two-state device) for code W then assumes the energized position "1" if either the odd-number-reversing or code-W relay is energized. It assumes the deenergized position "0" if both or neither are energized. This effectively reverses the state of the code W relay by substituting for it another relay whose state is properly modified by the state of the reversing relay.

The circuit in Figure 3 presupposes the use of a relay decoder, shown in the next section of this article. By definition, a cyclic code has only one

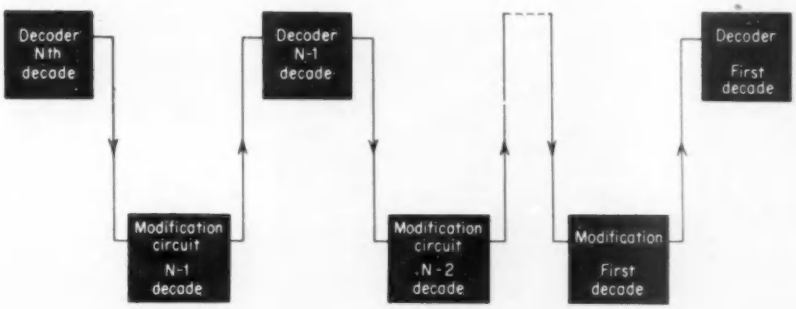


FIG. 1. Sequence of modification starting at highest order decade.

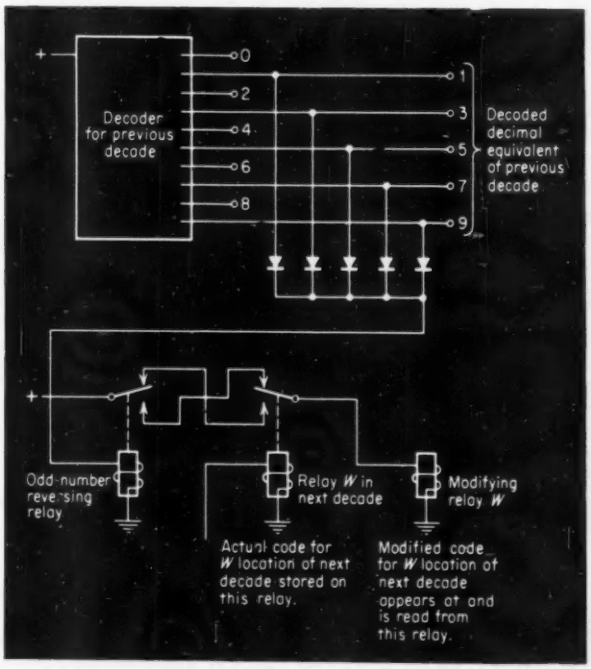


FIG. 2. General type of modifying circuit, usable with many different decoding networks.

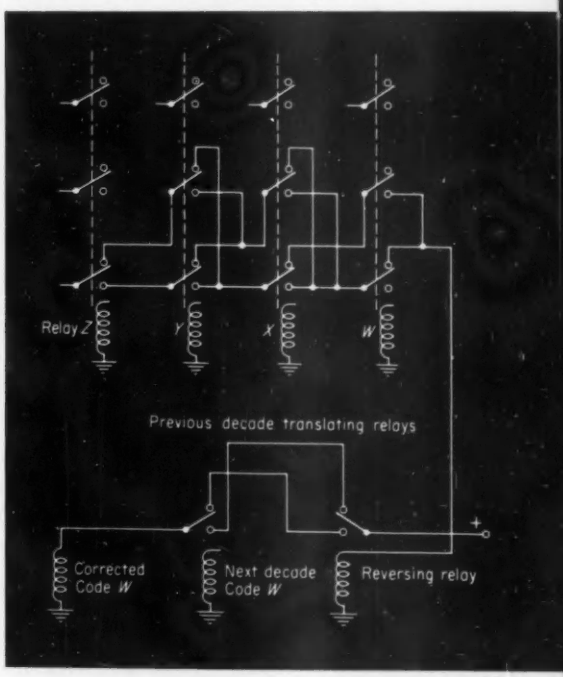


FIG. 3. Modification circuit for relay decoding network such as shown in Figure 4.

code for every increase or decrease of one in the equivalent decoded arabic number. The arabic number zero is coded 0000 in the cyclic binary-decimal code. It therefore follows that if none or an even number of code elements is energized (designated by "1" in the code) the translated digit is even. Conversely, if the energized number of code elements is odd, the arabic digit is odd. This can be seen by referring to Table I. All of the arabic numbers whose code contains none or an even number of "1's" are even, while all that contain an odd number of "1's" are odd. This concept is incorporated in the modification circuitry of Figure 3. The circuit energizes the reversing relay (and thus modifies the W code of the next decade) if an odd number of the W, X, Y, and Z relays of the preceding decade is energized.

Decoding circuitry

Once the proper modifications have been performed the cyclic binary-decimal code can be translated into decimal arabic numbers. After each sequential code correction, all designations assume the code shown for zero to nine in Table I. To set up the Boolean equations for decoding, the energized and deenergized state of the two-state values, W, X, Y, and Z are defined as follows:

w = The particular circuit element on the two-state device W that is in its energized position when the value W is in its "1" position. Conversely, the circuit element is in its deenergized position when W is in its "0" position.

w′ = The converse of w, or a particular circuit element on the two-state device W that is in its energized position when W is in its "0" position, or deenergized when W is in its "1" position.

The element w can be thought of as a normally-open contact on relay W, and w′ as a normally-closed contact. The code designations for zero to nine in Table I can then be rewritten in Boolean form as follows:

$$
\begin{aligned}
0 &= w' + x' + y' + z' \\
1 &= w' + x' + y' + z \\
2 &= w' + x' + y + z \\
3 &= w' + x' + y + z' \\
4 &= w' + x + y + z' \\
5 &= w' + x + y + z \\
6 &= w' + x + y' + z \\
7 &= w' + x + y' + z' \\
8 &= w + x + y' + z' \\
9 &= w + x' + y' + z'
\end{aligned}
$$

These simultaneous equations represent the decoding system necessary to convert to arabic numbers. For example, four relays, each with ten contacts that are normally opened or closed as shown in the above equations, will yield an arabic number at each of the outputs for each of the code designation inputs. The number of contacts can be reduced by using the notation:

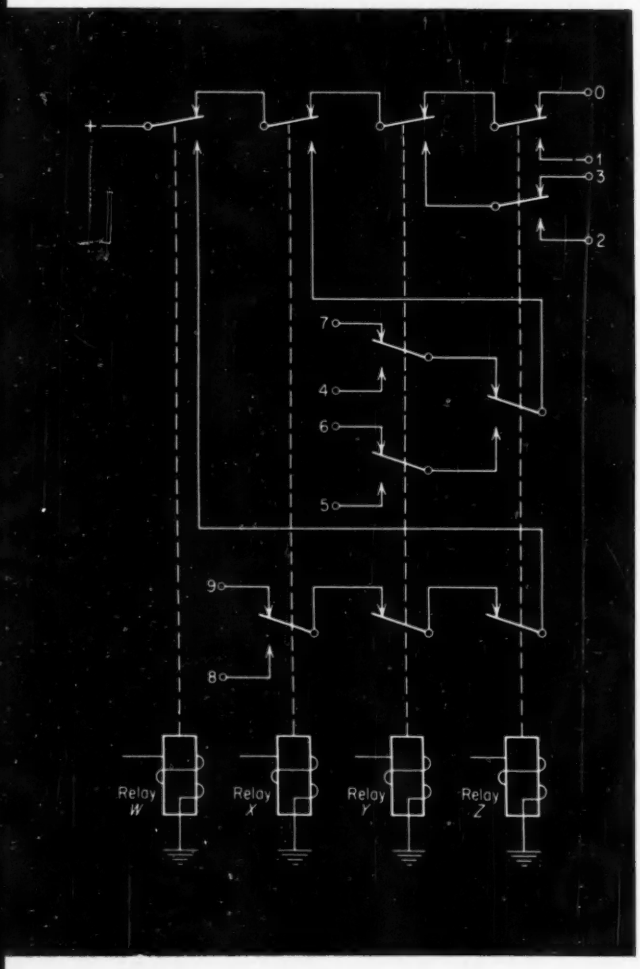
$\begin{vmatrix} w \\ w' \end{vmatrix}$ which has the concept of a single-pole, double-throw relay contact, where w′ is the normally-closed side and w the normally open side.

The simplified equation can then be rewritten:

$$
\begin{aligned}
&w' + x' + y' + \begin{vmatrix} z' \\ z \end{vmatrix} = 0 \\
&\qquad\qquad\quad \begin{vmatrix} z \\ z' \end{vmatrix} = 1 \\
&\qquad\qquad y + \begin{vmatrix} z \\ z' \end{vmatrix} = 2 \\
&\qquad\quad x + y + \begin{vmatrix} z' \\ z \end{vmatrix} = 4 \\
&\qquad\qquad y' + \begin{vmatrix} z \\ z' \end{vmatrix} = 6 \\
&w + \begin{vmatrix} x + y' + z' \\ x' + y' + z' \end{vmatrix} = 8 \text{ or } 9
\end{aligned}
$$

The 40 single-pole contacts have been reduced to nine single-pole, double-throw and four single-pole, single-throw contacts, with a maximum of six contacts per relay. A further reduction and more even distribution of contacts per relay can be obtained by rearranging the individual equations as follows:

FIG. 4. Simplified relay circuit for decoding cyclic decimal-binary code.



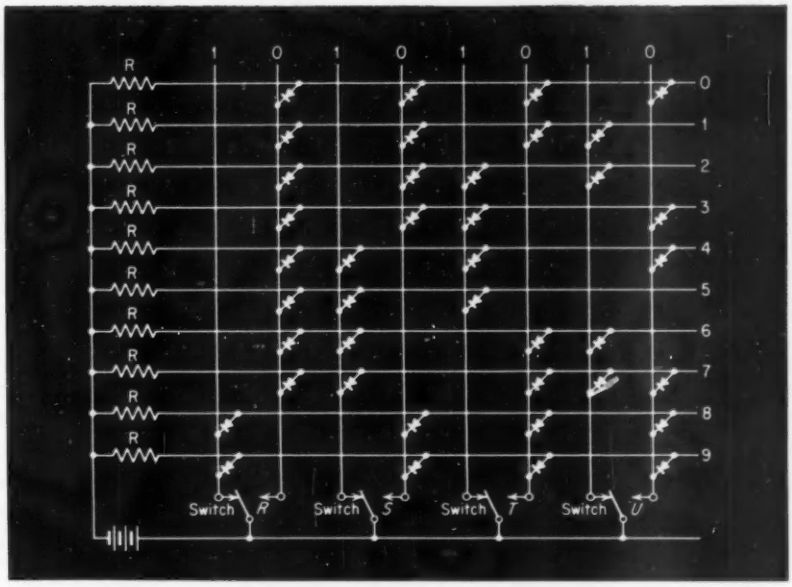


Fig. 5.
Rectifying decoding matrix.

$$
\begin{aligned}
0 &= w' + x' + y' + z' \\
1 &= w' + x' + y' + z \\
2 &= w' + x' + y + z \\
3 &= w' + x' + y + z' \\
4 &= w' + x + z' + y \\
5 &= w' + x + z + y \\
6 &= w' + x + z + y' \\
7 &= w' + x + z' + y' \\
8 &= w + z' + y' + x \\
9 &= w + z' + y' + x'
\end{aligned}
$$

The simplified relay arrangement is:

$$
\begin{vmatrix}
w' + \begin{vmatrix} x' + \begin{vmatrix} y' + \begin{vmatrix} z' = 0 \\ z = 1 \end{vmatrix} \\ y + \begin{vmatrix} z = 2 \\ z' = 3 \end{vmatrix} \end{vmatrix} \\
x + \begin{vmatrix} z' + \begin{vmatrix} y = 4 \\ y' = 7 \end{vmatrix} \\ z + \begin{vmatrix} y = 5 \\ y' = 6 \end{vmatrix} \end{vmatrix} \\
w + z' + y' + \begin{vmatrix} x = 8 \\ x' = 9 \end{vmatrix}
\end{vmatrix}
$$

This arrangement has nine double-throw and two single-throw, single-pole relays, and the maximum number of contacts per relay has been reduced from six to four. Figure 4 shows the final relay decoding circuit.

Matrix decoding

An analogy in equation derivation can be made to the above simultaneous Boolean equations to produce a decoding matrix equation. The definitions of the symbols are changed as follows: R, S, T, and U are the matrix analogies of the two-state values W, X, Y, and Z used above.

R = Switch pair with one side normally grounded and the other normally ungrounded.

r' = Connection from the output terminal line through a rectifier to the normally ungrounded side of the switch pair. This notation replaces the symbol "0" in the code designations.

r = Connection from the output terminal line through a rectifier to the normally grounded side of the switch pair. This replaces the symbol "1" in the code designations.

With these definitions, it is possible to transpose the code designations for zero through nine into the following simultaneous matrix equations.

$$
\begin{aligned}
0 &= r' + s' + t' + u' \\
1 &= r' + s' + t' + u \\
2 &= r' + s' + t + u \\
3 &= r' + s' + t + u' \\
4 &= r' + s + t + u' \\
5 &= r' + s + t + u \\
6 &= r' + s + t + u \\
7 &= r' + s + t' + u' \\
8 &= r + s + t' + u' \\
9 &= r + s' + t' + u'
\end{aligned}
$$

From these simultaneous equations the rectifier network needed to decode the cyclic decimal code can be specified immediately. This circuit is shown in Figure 5. For specific applications the equivalent network containing the appropriate forward and back resistance must be analyzed to find out if the ratio of signal to no-signal outputs is sufficiently large.

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Selecting Key Instruments for Nuclear Reactors

Harnessing the fission chain reaction of uranium and other heavy elements is a joint task for the control engineer and the nuclear engineer. "Control of Nuclear Reactors" by J. Dever, CONTROL ENGINEERING, August 1955, covered the principles of nuclear dynamics and control with which the control engineer must be familiar. Now co-authors Scott and DeBacker report on the state of instrument equipment and practice for nuclear reactors.

The article includes three charts for selecting neutron flux, temperature, and pressure measuring elements. Selection Chart 1 applies specifically to detection of nuclear activity. The remaining two are useful data file charts for selecting and specifying temperature and pressure measuring elements across industry.

C. C. SCOTT and T. A. DeBACKER
Minneapolis-Honeywell Regulator Co.
Brown Instruments Div.

Control systems for nuclear reactors consist of instrumentation to monitor and harness neutron flux density, temperatures, flows, liquid levels, pressures, conductivities, and pH. The requirements are peculiar to these two categories:

1) neutron flux control, always a primary factor in the selection of control systems for reactors of all types because it is effectively power level;

2) associated process control, in which the complexity and amount of instrumentation depend on the type of reactor under construction.

Neutron Flux Control

Figure 1, a block diagram of a nuclear control system, shows five primary channels: counting rate, period and log n (logarithm of the thermal neutron density), power level control, safety, and radiation monitoring. Figure 2 shows the physical arrangement of console-mounted amplifiers and recorders. Common to all five channels is a means of detecting neutron flux. There are three types of neutron flux detectors:

▶ BF_3 proportional counter, a metal cylinder filled with boron trifluoride gas and a tungsten wire center conductor. A high potential applied to the electrodes causes each boron disintegration occurring in the counter to generate a pulse charge at the collecting electrode.

▶ Fission chamber, which has electrodes coated with uranium oxide enriched in U-235. Upon capturing neutrons, the uranium nuclei fission and emit heavy particles, ionizing the surrounding gas.

▶ Boron-lined ionization chamber. A typical minus-35 vdc applied to the chamber with a positive operating ac voltage compensates for gamma radiation.

The three types of neutron flux detectors, when arrayed strategically near the reactor core, produce signals proportional to neutron flux over the entire range of reactor operation. Selection Chart 1 compares detector outputs in current or counts per sec for different levels of neutron flux. To minimize transmission losses, the detectors are connected to amplifiers at the control console with RF coaxial cable of a capacitance on the order of 20 $\mu\mu$f per ft.

Counting rate channel

Having a neutron flux range of four decades, the counting rate channels provide the operator with complete information for reactor startup, that is, for taking the reactor from source level through the sub-critical state, the condition at which neutron production just equals absorption plus leakage. Figure 1 shows that counting rate channels include a neutron detector (BF_3 proportional counter or fission chamber), preamplifier, linear amplifier, scaler, log count rate meter, and perhaps a low-level period amplifier. The number of counting rate channels depends on reactor size, geometry, and power level.

A reactor with a small, compact core designed for low-power-level operation will have one channel. But a larger reactor that operates over 12 to 14 decades, from source level to full power level, will require two or more. In this case, the neutron flux

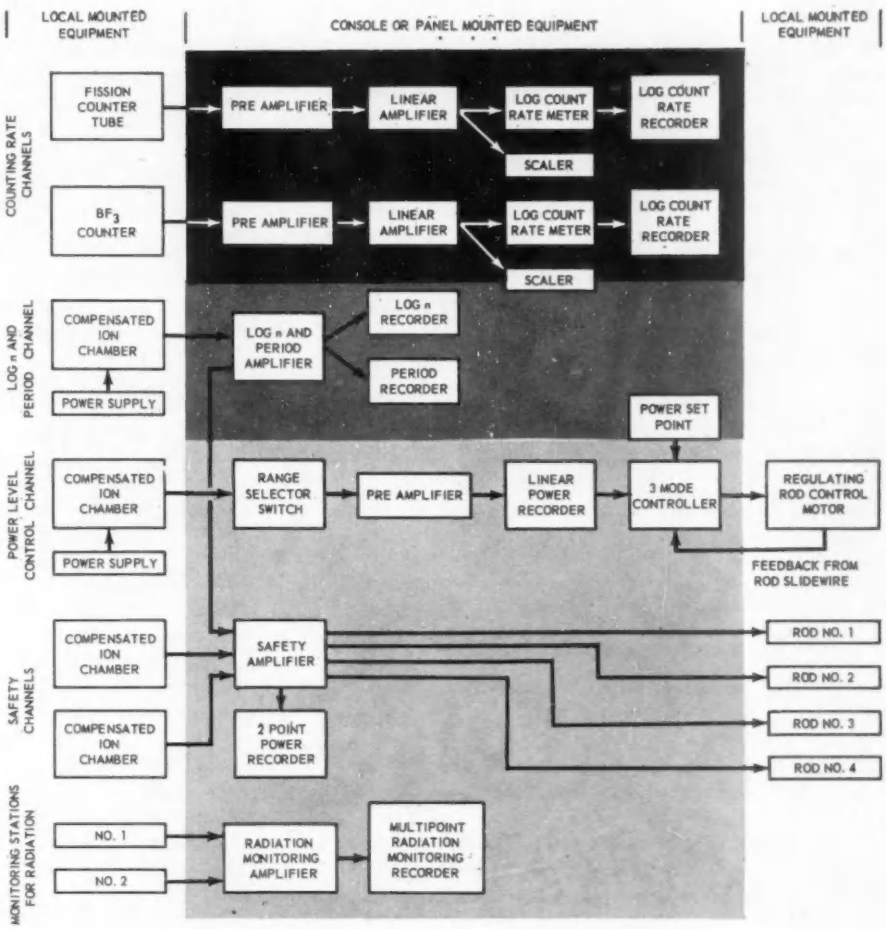


FIG. 1. Five channels measure, indicate, control, monitor, and assure the safe operation of a nuclear reactor all the way from source level to operating nuclear power level, 10 decades above source level.

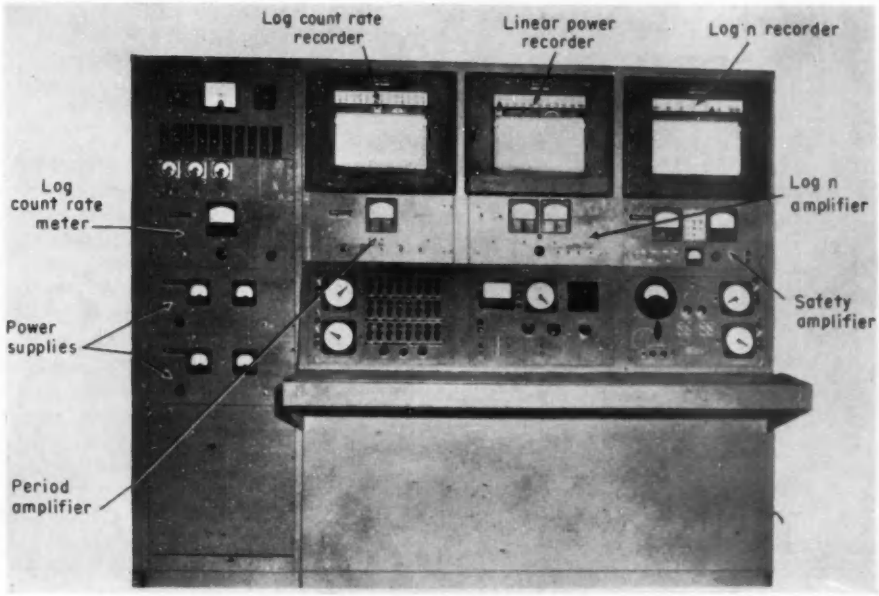
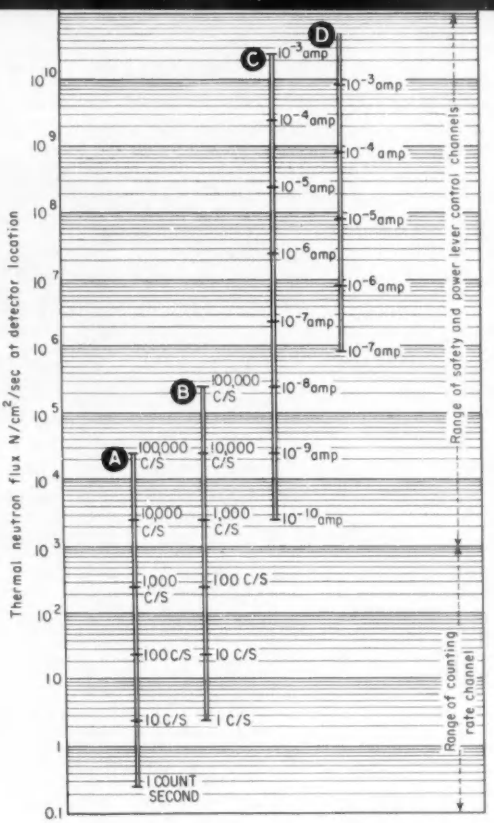


FIG. 2. Operator supervises nuclear activity of reactor from a console containing the instruments and recorders blocked out in Figure 1.



SELECTION CHART 1. Control systems engineer can select neutron flux detectors with overlapping ranges for all five channels in a neutron flux control system (courtesy of Westinghouse Electric Corp.): (A) Single element BF_3 WL 6307 4 counts/sec/neutrons/cm²/sec. Gamma discrimination 150 volts. Plateau at 75 Roentgens/hr. (B) Fission counter WL 6376 4 counts/sec/neutrons/cm²/sec. Gamma discrimination possible: 99% at 10^{-4} Roentgens/hr. (C) Electrically compensated ion chamber WL 6733 14 x 10^{-4} amps/neutrons/cm²/sec may be used uncompensated down to where fixed gamma background current approaches neutron current. Gamma sensitivity 3 x 10^{-11} amps/Roentgens/hr. (D) Fission chamber WL 6376 1.2 x 10^{-13} amps/neutrons/cm²/sec. Alpha current of 10^{-6} amps limits lower level of use. Gamma sensitivity 3 x 10^{-11} amps/Roentgens/hr.

detector for the second channel is located so that its neutron sensitivity begins when the first channel approaches its effective limit.

A pulse-height discriminator in the linear amplifier discards the smaller detector pulses due to gamma radiation and transmits only those resulting from neutrons. This discrimination is important when the reactor is restarted so soon after a shutdown that induced gamma radiation has not dissipated. With a pulse width of 0.6 microsec and a 3-volt swing, the output of the linear amplifier drives a log count rate meter and a scaler. The log count rate meter develops an output voltage proportional to the logarithm of the number of input pulses per sec, from 1 to 10,000 counts per sec. An electronic scaler counts the pulses passed by the linear amplifier, indicating the total number of neutron interactions with the neutron detector. A mechanical register extends the electronic counter's range. Equipped with a timer, the scaler will measure the number of pulses in any set time interval.

Period and log power channel

As soon as the period and log power channels become sensitive, the operator takes the reactor from its critical state to its power operating range, a span of six decades. Like the counting rate channel, the period and log power channel consists of a neutron-sensitive ionization chamber, its power supply, a period and log power amplifier, a log power recorder, and a period recorder. Besides providing information for taking the reactor to its operating level, this channel, connected with the safety circuits, shuts down the reactor if the power rises too rapidly. Differentiation of the log power signal with respect to time measures the reactor's period, the time for the reactor power to change by a factor of e, the Naperian base, or 2.718. Although the trip point of the period meter is adjustable from minus 30 to plus 3 sec, it is normally set at 3 sec to trigger the scram circuit, releasing the safety control rods. The log power recorder can contain auxiliary safety switches to sound a warning at 10 percent above the operating power level or to shut down the reactor at 50 percent above the operating level.

Power level control channel

Controllers, little more than withdraw- and insert-relays in simple reactor control systems, automatically maintain the set power level by positioning regulating rods in some relation to the deviation between the set and measured power levels. In the power level control channel shown in Figure 1 there are an ionization chamber, its power supply, a linear power recorder, a regulating rod drive motor, a rod position feedback slidewire, and a controller with proportional, error rate, and time-integral actions. The integration moves the control rod until the power level error is zero when reactivity changes occur due to fuel burn-up, fuel-poisoning, and temperature.

A power reactor control system is designed to balance nuclear power against electrical load changes at the generator. The primary signal may originate

from a reactor coolant outlet temperature or from an element sensing electrical load. If the signal indicates an increase in electrical load, the controller will move the rods to increase the nuclear power output. While the reactor rises to a new operating level, neutron flux and reactor period signals can override the primary signal to prevent power excursions.

Safety channel

The control system designer must provide a means to prevent the reactor at any time from rising on a fast and damaging period, and from exceeding a predetermined power level, even if approached on a relatively long period. The safety channel shown in Figure 1 is an answer. A group of ionization chambers connected to the safety amplifier provide the power information for safety action and for power recording. The safety amplifier lends itself to coincident connection with amplifiers in other channels to assure continuous safe operation in the event one channel requires maintenance. The amplifiers are so connected that two or three channels have to agree before a scram occurs, although a period scram normally overrides any other coincident signal. Magnets or magnetic clutches powered by the safety amplifier support four separate safety rods containing several percent of negative reactivity. Always in a position to scram the reactor when released by the magnetic holding devices, the safety rods can scram "fast" or "slow". A signal of too high a level or too short a period initiates the "fast scram". "Slow scrams" result from abnormal process variable conditions, such as: low flows, excessive temperatures, abnormal liquid levels, or high and low pressures.

The safety amplifier also operates a multi-point power recorder which continuously records power signals from each ionization chamber. A light-up annunciator on the safety amplifier indicates:

1) breaks in the coaxial cables leading from the ionization chambers
2) occurrence of fast scram and the ionization chambers sensing it
3) heater burnout in the tubes supplying current for the magnetic rod-holders

Radiation levels at remote locations are recorded by the radiation monitoring channel shown in Figure 1. Meter relays warn the operator through the annunciator system and initiate a slow scram when radiation levels become excessive.

Associated Process Control

Primary coolant circulated through the reactor acquires heat, which is released at an exchanger to

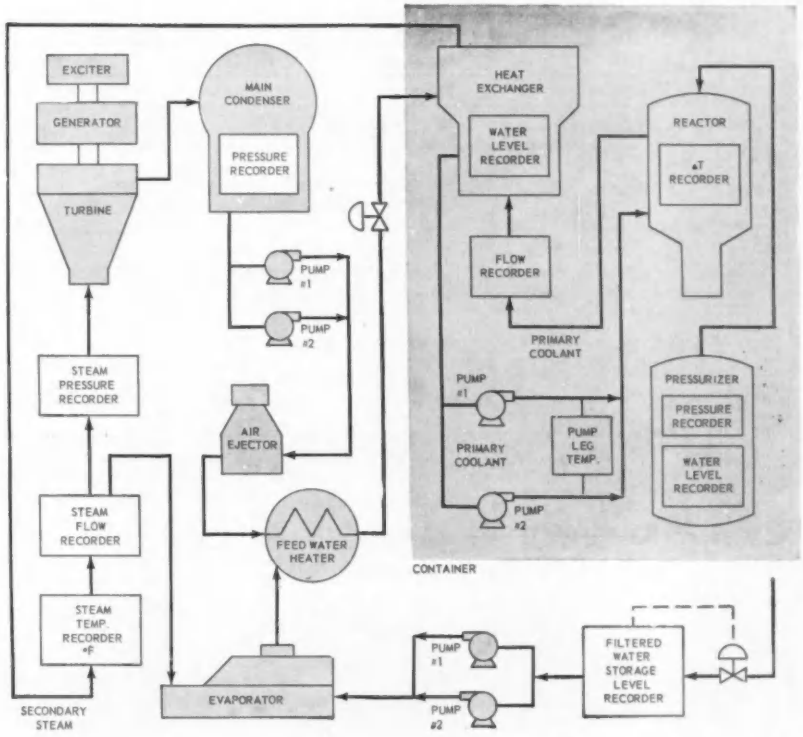
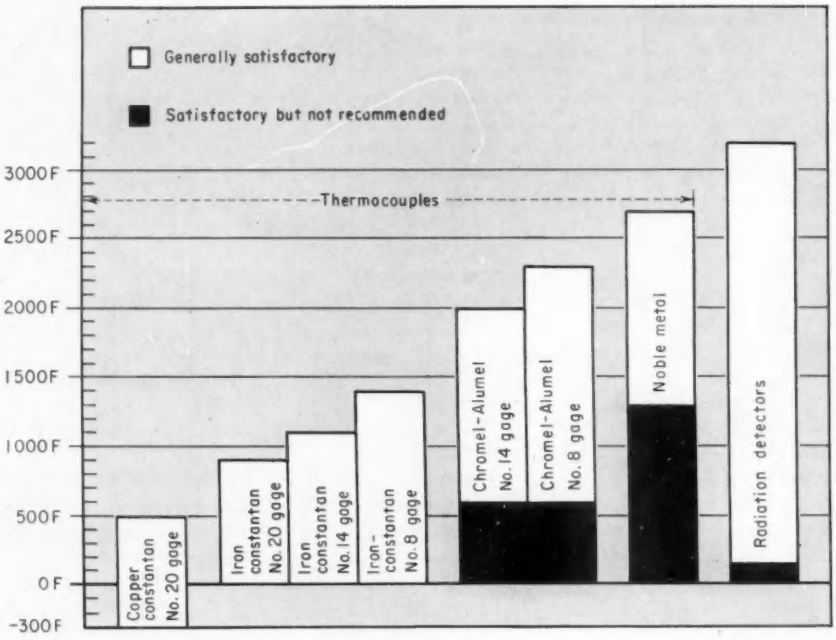


FIG. 3. A pressurized-water-cooled reactor providing the thermal energy demanded by a steam turbine requires a wide range of temperature- and pressure measuring elements.



SELECTION CHART 2. Working ranges of thermocouples and thermal radiation detectors overlap for application to all processes, including those associated with a nuclear reactor.

TYPE	MATERIAL	APPLICATION	MINIMUM RANGE	MAXIMUM RANGE
SPIRAL				
	Bronze	Compound vacuum and pressure Gage pressure	6.5 psig* 0 to 18 psig	15 psig* 0 to 400 psig
	Steel	Gage pressure	0 to 30 psig	0 to 4,000 psig
	Stainless steel	Gage pressure	0 to 50 psig	0 to 4,000 psig
SPRING AND BELLOWS (Inside of case)				
	Brass	Gage pressure Vacuum	0 to 90 in. water 0 to 10 in. mercury vacuum	0 to 16.3 psig 0 to 30 in. mercury vacuum
	Stainless steel	Gage pressure	0 to 15 psig	0 to 40 psig
EXTRA LARGE SPRING AND BELLOWS (Back of case)				
	Brass	Gage pressure Vacuum Compound vacuum and pressure	0 to 5 in. water 0 to 5 in. water vacuum 5 in. water*	0 to 90 in. water 0 to 60 in. water vacuum 80 in. water*
ABSOLUTE PRESSURE BELLOWS				
	Brass	Absolute pressure	0 to 100 mm mercury absolute	0 to 50 in. mercury absolute
	Stainless steel	Absolute pressure	0 to 200 mm mercury absolute	0 to 60 in. mercury absolute

*Value represents span of compound element, instead of range.

NOTES:
Spiral elements are available with suppressed ranges, such as 1,000 to 4,000 psig. Amount of suppression can be 50%, 25%, or less than 25% of full scale.

SELECTION CHART 3. Commercially available pressure measuring elements fit the instrumentation requirements of a water-cooled nuclear reactor.

generate steam for a turbine. The associated process part of the reactor control system consists of instrumentation for measuring and controlling the temperatures, pressures, levels, flows, pH, and other variables of the thermal processes associated with the reactor. Figure 3, a schematic of a graphic panel containing diagrams of process equipment, a process "roadmap", process variable recorders, and warning lights, shows the type of process instrumentation involved in a pressurized-water reactor.

Until confidence in the control system is firmly established, the trend will be toward isolating the reactor and its primary coolant circuit in a structure which can contain radioactive gases during an emergency. The dark gray outline in Figure 3 represents the container. Because access to the container's interior is impossible for long periods of time, the primary measuring elements must be able to withstand high radioactivity, resist corrosive circulating fluids, operate at high ambient temperatures and 100 percent humidity, and work reliably for several years. The trend in transmission has been toward electric rather than pneumatic because of the possibility of pneumatic lines carrying contaminants.

Thermocouples and resistance thermal elements measure temperatures of primary coolant and secondary steam. Though thermocouples operate at maximum sensitivity without protective wells, these wells are required in most applications to prevent chemical and mechanical injury to the thermocouple. Stainless steel wells are a compromise between protection and speed of response. Selection Chart 2 compares the ranges of suitable thermocouples. One would select an iron-constantan thermocouple to measure the steam temperature (up to 700 deg F) in the secondary steam circuit, for instance. Extension wires connect the thermocouples to an electric-to-pneumatic converter located behind the graphic panel. The pneumatic signal drives a recorder and safety switches.

Selection Chart 3 gives the operating ranges and general applications of pressure measuring elements, many of which would be used in the instrumentation of the primary coolant and the secondary steam. Operating at up to 500 psig, the pressure element for the secondary steam is made of stainless steel. The transmitter is pneumatic and located near the measuring point. Again, the transmitted pneumatic signal drives a recorder and safety switches.

Safety switches carry out the control philosophy for the associated processes—they warn the operator through an annunciator system and, through the safety channel, start a slow scram. The table is a typical alarm sequence for an annunciator. The operator acknowledges audible alarms by pressing a button, but lights and target drops remain visible until the alarm fault is corrected.

Maximum reliability for a reactor control system is essential. All major components must be designed for fail-safe so that upon their failure, the reactor automatically scrams. Gravity, because of its certainty, is depended on to drive the safety rods into the reactor when released by the magnetic holders in the safety channel.

Alarm Sequence of an Annunciator for Processes Associated with Reactor

Alarm device	Normal	Off-normal alarm	Silence	Normal again
Lamps	off	flashing	bright	off
Audible	off	on	off	off
NO trouble contact	open	closed	closed	open
Reset PB	closed	closed	depress	closed

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Are High Performance and Low Cost Compatible in Hydraulic Servos?

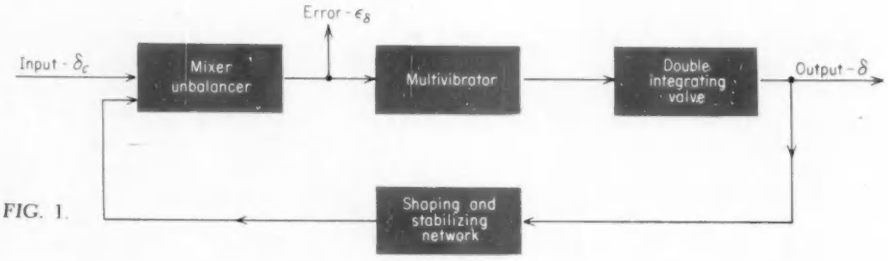


FIG. 1.

JOHN G. CHUBBUCK
Johns Hopkins University

The principal difficulty in designing a high-performance hydraulic servo valve has been the extremely tight tolerances on the metering orifices. These tolerances are classified as underlap or overlap. Underlap results in severe softening of valve gain in the low-flow region, whereas overlap not only softens the low-flow gain but also results in poor position resolution of the entire servo system. High precision valves tend to become underlapped with erosion of the sharp corners on the lands.

Conventional valves often display loss of gain at high flow rates due to nonrectangular port shape or loss of pressure differential across the metering orifices. This effect, coupled with the softening of gain at low flow rates, results in a flow gain characteristic which is highly nonlinear in valves not having extremely tight machining tolerances.

Another nonlinearity encountered in conventional valves is the tendency of the spool to stick due to side loading effects of the high pressure oil and collection of dirt at the edges of the metering orifices.

The purpose of this article is not to attempt to eliminate inherent nonlinearities of the spool-type valve, but to devise an information transmission technique that is less affected by these nonlinearities than conventional servo systems. This technique consists of a high frequency forceful switching process of driving the valve. The valve itself has been slightly altered so that now it is a double integrating device. Because of the double integration, the switching process has the physical significance of switching output member acceleration.

General system arrangement

The difference between the acceleration switching hydraulic servo and the more common linear servos is more in the operation than in the physical configuration. The acceleration switching servo is a dual mode system—when the servo error becomes sufficiently great to call for an acceleration greater than the limit value, switching stops until the error becomes less than the mode changing value.

Figure 1 shows a block diagram of the acceleration switching servo made up of its four distinct components.

The mixer-unbalancer of this system is similar to the first amplifier stage of a linear servo system. Its function here, however, is primarily that of controlling the pulse proportioning of the multivibrator rather than amplifying the error signal. In either case, this stage is the error measuring device.

The multivibrator generates the switching action and is probably the most radical departure from linear servo concepts of any component in the system. Dwell time of the multivibrator in each stable condition is a function of the RC time constants of the grid circuits and the potential of the unbalancer plates. Since the multivibrator grid circuits are alike, the multivibrator generates a balanced square wave when the unbalancer plates are equal in potential (when error is zero). When the unbalancer is not balanced, dwell time of the multivibrator will be increased in one condition and decreased in the other, giving the multivibrator output a dc component proportional to error while not materially changing the pulse repetition rate (i.e., the switching frequency). Control is derived from changes in the average value or "dc component" of the multivibra-

THE GIST: Inherent nonlinearities in conventional spool-type hydraulic valves have been the chief stumbling block in developing high performance hydraulic servos. Past efforts to cope with these problems by tightening up machining tolerances have not resulted in a low-cost, mass-producible hydraulic value that could still be considered a high-performance device.

Recent experiments have resulted in the use of a new method for overcoming the harmful effects of these nonlinearities. This technique is similar to that used in linearizing contactor servos and friction-disc clutch systems. In this case, it consists of a high-frequency forceful switching process for driving the valve.

"Linearized" dynamic response characteristics for both a position servo and a rate servo are shown here. These experimental results were obtained from a modified conventional valve. A valve designed specifically for this purpose could conceivably have half as many parts as the conventional type, and give the same high performance at an even lower cost.

tor output—here referred to as an average value since the repetition rate is high compared to the highest control frequency of interest. The unbalancer and multivibrator are shown in Figure 2. Switching frequency for the parameters is about 200 cps.

Figure 2 also shows the mechanism for changing from the switching to the nonswitching or "outer mode" of operation. When the error becomes sufficiently large to drive one unbalancer plate below the multivibrator cutoff potential, the multivibrator section connected to that plate will remain in a nonconducting state as long as that condition exists.

The cathode followers couple the multivibrator to the valve torque-motor without disturbing the mode of operation of the multivibrator.

The double integrating hydraulic valve is shown in detail in Figure 3. This valve is essentially identical to the double-nozzle, linear, hydraulic-amplifier type except that it has no spring restraint on the spool. In fact, an altered linear valve has been used in an experimental acceleration-switching servo. This valve will be discussed in more detail later.

The multivibrator, driving the torque motor through the cathode followers, switches a current of 10 mils alternately from one-half of the torque motor coil to the other at the repetition frequency. This results in the flapper capping off one nozzle during the dwell time in one stable condition and capping off the other nozzle during the other dwell period. The time required for the flapper motion is small compared to the time a nozzle is capped off when the multivibrator is balanced.

High-pressure oil around the center land of the spool bleeds through the small orifices into the control chambers at the ends of the spool. If the nozzle is not capped off by the flapper, this flow escapes

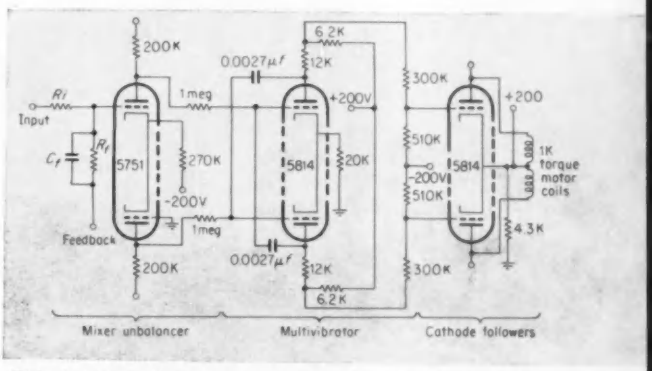


FIG. 2. Electronic portion of acceleration switching servo

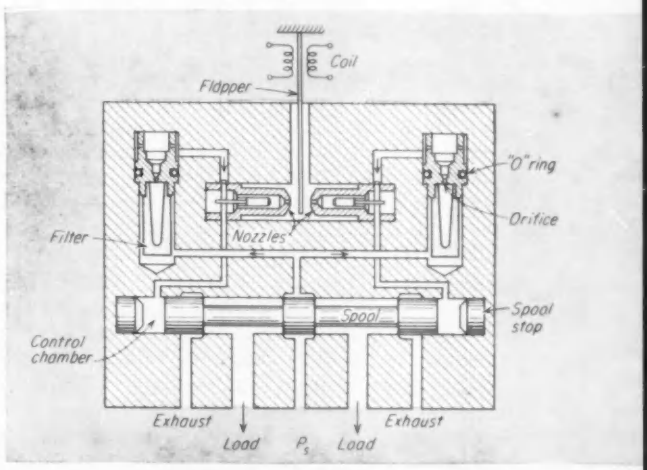


FIG. 3. Schematic diagram of a hydraulic acceleration switching valve (modified Conventional Valve)

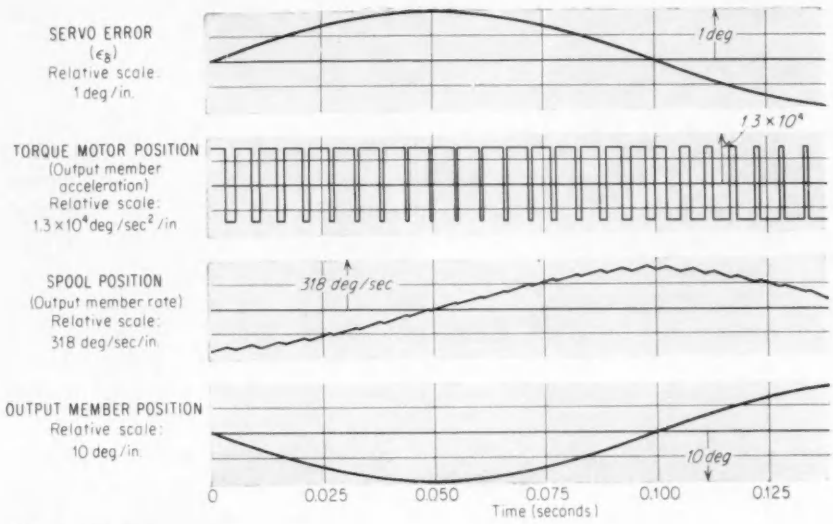


FIG. 4. Waveform diagram

out the nozzle. With the nozzle capped off, however, the flow through the orifice accumulates in the control chamber, forcing the spool toward the opposite end. This gives a spool position that is the time integral of the approximately constant flow through the orifice over the period in which the nozzle is capped off.

The second integration results from the normal integral relationship between position of the output member and position of the hydraulic valve spool.

The feedback network, shown in Figure 1, serves two purposes—it must supply sufficient phase lead to stabilize the loop, and also provide considerable opportunity for shaping the closed-loop frequency response characteristics. A position servo can be realized by the use of a feedback network with a transfer function of the form $[1/\alpha][(\alpha\tau s + 1)/(\tau s + 1)]$ and a rate servo with a feedback transfer of the form $\tau s/(\tau s + 1)$. Both transfer functions represent simple, easily attained, passive networks.

Performance characteristics

The waveform diagram of Figure 4 illustrates qualitatively the acceleration switching mode of operation. Error ϵ_δ is an arbitrarily-chosen, sinusoidal function that may be thought of as the unbalancer differential plate voltage. The second waveform represents the variable dwell-time switching process as it would appear in the output of the multivibrator. This output has the physical entity of servo output member acceleration, $\ddot{\delta}$. As was mentioned before, hydraulic spool position is the first integral of the multivibrator output. Spool position is represented in Figure 4 by the third waveform and has the physical entity of servo output member rate, $\dot{\delta}$. The fourth waveform of Figure 4 is that of output member position, δ, which, as indicated, is the integral of spool position.

Since the present interest in performance characteristics lies in a frequency range whose upper limit is far below the switching rate, the primary concern is with the relationship between the differential voltage input to the unbalancer and the "average" multivibrator output (averaged over a number of switching cycles). Average acceleration output of the multivibrator is

$$\left[\frac{T_1 - T_2}{T_1 + T_2}\right] \times [\ddot{\delta}\ \text{limit}]$$

where T_1 is the period in which the multivibrator is switched to the positive acceleration limit and T_2 the period in which it is switched to the negative limit.

The gain, K, of the unbalancer-multivibrator combination may be defined as the average acceleration output from the multivibrator per differential volt into the unbalancer.

Figure 5 shows the measured gain characteristic of the unbalancer-multivibrator (Figure 2). This curve is based on an acceleration limit of 10_4 deg/sec^2. In the neighborhood of zero error voltage the gain is seen to be approximately 8,500 deg/sec^2/volt. The nonlinear gain characteristic near the mode change position shows that the multivibrator pulse of diminishing time has not reached zero time when mode change occurs.

It is now possible to express the forward loop of the servo in transfer function form. But it must be remembered that the transfer functions are meaningful only at frequencies low compared to the switching rate. The forward loop transfer function is

$$\frac{\delta}{\epsilon_\delta} = \frac{K}{s^2}$$

Experimental positional servo

A limited experimental study has been made of a position hydraulic servo employing this acceleration switching technique. Figure 6 shows, in transfer function form, the servo configuration used.

The closed-loop response characteristic of this system is

$$\frac{\delta}{\delta_c} = \frac{1.75(0.00238s + 1)}{(1.67 \times 10^{-7})s^3 + (7 \times 10^{-5})s^2 + 0.0167s + 1}$$

Plotted in Figure 7, this shows that the system is positional in nature even though the feedback is a lead network. This results from the fact that the frequency region in which the feedback network has phase lead is higher than that in which the closed-loop characteristic is positional. The necessity of phase lead in the feedback arises from the double integration in the forward loop which would be inherently unstable without phase lead.

Frequency response measurements have been made at various input amplitudes from 0.055 to 12.7 deg and over a frequency range from 1 to 30 cps. Results are plotted in Figure 8 as a composite plot to show the lack of amplitude sensitivity. The sharp discontinuity in the two largest amplitude cases results from the fact that the rate limit (200 deg/sec) of the system is reached at these conditions of amplitude and frequency.

The switching process effect should be considered in terms of how much output member movement results from acceleration switching and the amount of servo power thus consumed. In the case of the experimental system being considered, the acceleration limit is 10^4 deg/sec^2. Since the acceleration form is square wave, amplitude of the fundamental Fourier component is $(4/\pi) \times 10^4$, which is filtered by the following double integration, giving a switching activity amplitude in the output member of

$$\frac{\left(\frac{4}{\pi}\right) \times 10^4}{[2\pi(200)]^2} = 0.^\circ 08 \text{ deg},$$

when the switching frequency is 200 cps. Obviously, higher harmonics of the square wave of acceleration need not be considered because of their even greater attenuation.

Consumption of hydraulic power due to switching can best be expressed in terms of a percent of the rate limit value. During one average dwell period, the change in output member rate is the product of the acceleration limit times the dwell period:

$$10^4 \times \frac{1}{400} = 25 \text{ deg/sec}.$$

However, the rate change is from 12.5 deg/sec in one direction (assuming zero input signal) to 12.5 deg/sec in the other direction. This results in an average output member-rate magnitude of 6.25 deg/sec, which, in this case, is slightly over 3 percent of the rate limit value.

Experimental rate servo

An experimental rate servo has also been considered, although no documentary test data have

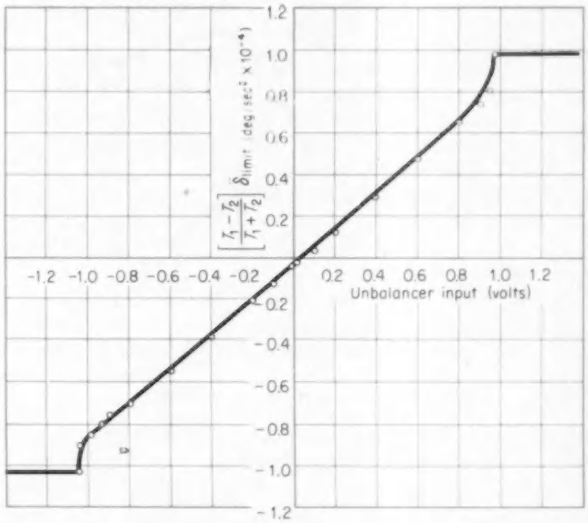


FIG. 5. Unbalancer-multivibrator gain characteristic curve

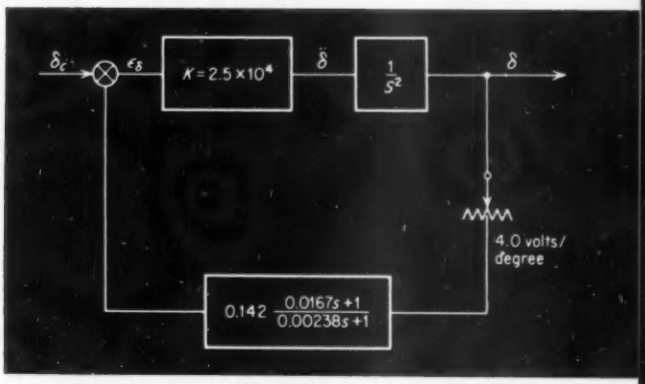


FIG. 6. Block diagram of position servo

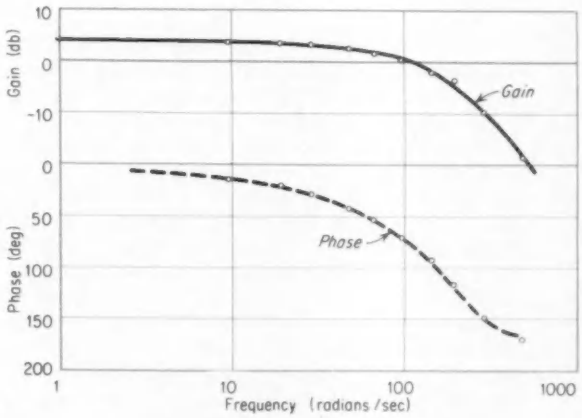


FIG. 7. Position servo—computed response

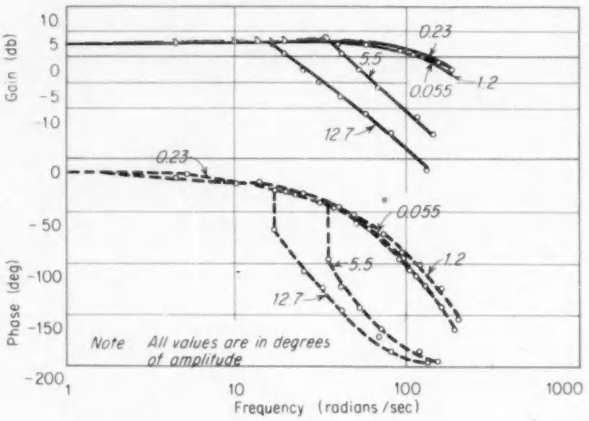


FIG. 8. Frequency response composite plot of data at various input amplitudes

been taken on this system as a rate servo by itself. The system considered is shown in Figure 9.

The computed frequency response characteristic of this servo (Figure 10) is compared to an ideal rate servo characteristic of 100/s. As can be seen, the acceleration switching system is a good approximation of the ideal in the frequency region from zero to about 16 cps. Since between the multivibrator and the output member the system is essentially the same as the positional servo, output member activity and hydraulic power consumption due to switching are not materially changed.

Advantages of the technique

Advantages of the acceleration switching system:

- increase of servo resolution, both rate and position, compared to linear systems
- relaxation of machining tolerances on the hydraulic valve by an order of magnitude
- increase of servo reliability

Resolution

If the concept of resolution were to be based on instantaneous resolution of output member position or rate, then resolution of this system would be the position or rate amplitude of the output member due to the switching activity. However, because of the high frequency of switching, it is unlikely that the load driven by the servo (missile aerodynamics, for example) would respond to this activity in any undesirable manner. It would be of greater significance to base the idea of resolution on the accuracy with which the "dc level" of the output position or rate can be controlled. Here, "dc level" implies the average output over a number of switching cycles. Unlike the common "linear" servos, the experimental position servo showed no observable resolution limitation caused by hydraulic valve nonlinearities. Small sine wave inputs were observed in the output down to the amplitude at which the noise level obscured the signal. It appears that the noise level is the important factor in limiting resolution of this system.

Some of the sources of noise that contribute to resolution limitation of this system are:

- multivibrator jitter
- failure of the hydraulic switching process to repeat itself exactly cycle after cycle
- fluctuations in hydraulic pressure
- imperfect regulation of power supplies
- feedback pot noise

Machining tolerances

To make a conventional hydraulic valve (Figure 11) approximately linear, machining tolerances on the valve spool must be held quite tight. Such tolerances are hardly conducive to low-cost, large-quantity production.

By keeping the spool amplitude due to switching large compared to the tolerance, the switching system permits the use of tolerances of at least one order of magnitude greater than those in conventional systems without noticeable nonlinear effects on the closed-loop characteristic. A reasonable ratio between spool peak-to-peak amplitude due to switching and tolerance on spool dimensions seems to be about 5 to 1.

The tolerance on clearance between the spool

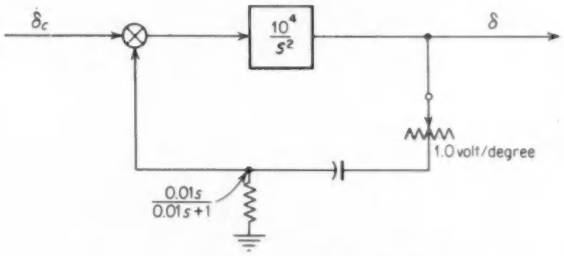


FIG. 9. Rate servo block diagram

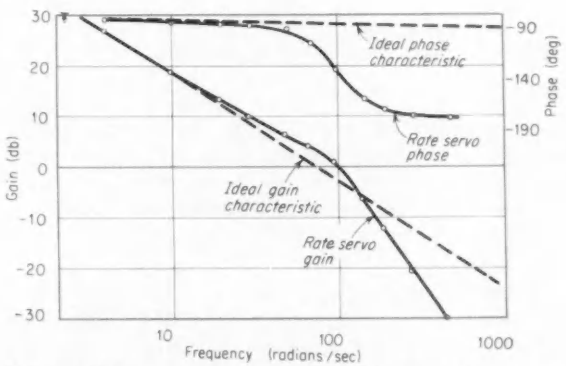


FIG. 10. Rate servo frequency response characteristic curves

and its insert is not materially altered by the switching technique, since this is primarily a leakage consideration.

Another rather critical tolerance in hydraulic amplifier-type linear valves is proper spacing of nozzles on opposite sides of the torque motor flapper to maintain linearity between control chamber differential pressure and flapper motion. In the acceleration switching system, there is no necessity to maintain this linearity since the function of this part of the system has been reduced to simplify a switching process. For the switching system, separation of the nozzle should be somewhere between 0.003 and 0.006 in. plus the thickness of the flapper. Separations of less than 0.003 in. are not advisable because of the chance of dirt collecting at the nozzle's tip, whereas separations greater than 0.006 in. make the switching time unnecessarily long.

The switching technique demands no special tolerance on the inside diameter of the nozzles; however, it must not be so large that the torque motor is incapable of capping off against the line pressure. One important consideration in the capping-off process is that the flapper should seal the nozzle sufficiently in order to make the effective orifice size of the capped nozzle small compared to the upstream orifice size. Then the net flow into the control chamber, during the capped-off period, will not be greatly affected by the completeness of capping.

In the conventional valve, flow rates of the orifices must be sufficiently equal to require matched pairs. The switching system, however, is not seriously affected by somewhat unequal flow rates, since the resulting misalignment is more nearly absorbed by the higher servo loop gain.

Although it cannot be considered a machining tolerance, the valve ports in the acceleration switching system need not be rectangular in shape since the double integration in the servo forward loop makes it a zero-velocity error system. Round drill holes are probably the most practical port shape.

Reliability

It is difficult to say at this time what relative degree of reliability of the acceleration switching system is due to incomplete evaluation. It does seem fair to state, however, that relaxing valve tolerances implies an increase of reliability. The greatest increase in reliability over a linear hydraulic servo undoubtedly comes from the substitution of a very forceful switching process for a system in which incremental changes of signal amplitude must be controlled. The power of the switching process may be appreciated by a look at the previously discussed experimental position servo. The torque motor coil current (10 ma), switched between the two halves of the coil, is roughly twice as great as necessary for the switching process. The resulting torque motor force is nearly three times as great as is needed to cap off the nozzle against full line pressure (1,500 lb/in.^{2}). Furthermore, the maximum available force on the spool (about 50 lb) is much higher than that needed to overcome hydraulic reaction forces, spool friction, and acceleration forces. One might say that the element of precision has been removed from the hydraulic system and is now a function of how closely the pulse proportioning of the multivibrator can be controlled. Simplification of the dirt problem should also increase reliability. As was mentioned, dirt is less likely to collect between a nozzle and the flapper because of the greater space between them. Also, the abundant force available on the spool has a tendency to shear through dirt particles in the valve ports without disturbing the operation of the system.

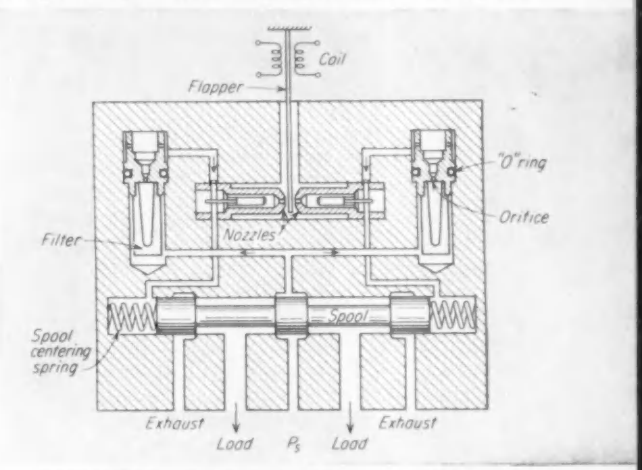


FIG. 11. Schematic diagram of a conventional hydraulic amplifier type valve (compare with Fig. 3)

Future effort

As indicated, considerable work is yet to be done to determine the reliability of the acceleration switching system. To-date work on this system has been entirely of a research and development nature, and much effort is yet to be directed toward determining what latitude exists as to achievable closed-loop response characteristics, either as a position or a rate servo. Related to this effort will be that of minimizing the time required to reverse direction of spool motion, since this places a limitation on the highest stable value of loop gain.

Future work should be directed also toward reducing the actual number of parts required in such a valve. With careful attention to design, it might even be possible to produce an acceleration switching valve, with half the number of parts found in a conventional servo valve.

Pulse Synchronizing for High-Gain Servomechanisms

High-performance servomechanisms have narrow proportional bands that often make them unstable to very large step inputs, such as those encountered at system startup. The circuit described here produces a decelerating pulse as the system approaches zero error, thus allowing the system to synchronize to its reference input at the maximum speed without overshoot. The form of the synchronizing pulse is derived for a typical positioning servo.

G. H. FRIEDMAN, Burroughs Corp., and M. SCHWARTZ, The Franklin Institute

High-performance servos use high-gain amplifiers to keep the error between output and input as small as possible during normal operation. This gain reduces the range over which the servo acts proportional to the error input, since it lowers the input voltage for which the tubes and transformers in the output stages of the amplifier will saturate. Beyond saturation, no amount of error increases the output appreciably, so that saturation represents maximum servo output. In the case of a position servo system, it represents full speed for the servomotor.

An idealized saturation curve is shown in Figure 1. In systems that make maximum use of the available range of the components used, an error of only a few minutes of arc can produce saturation.

Unfortunately, a small proportional band causes synchronizing difficulties when a servo system has just been energized or when a large step input is applied. If the initial error is large enough, the system can attain maximum velocity before the error falls within the proportional band. Then, if the proportional band is small, the inertia of the load and lags in the system causes the servo to overshoot the proportional band into the saturation region on the opposite side. If the proportional band is small enough, the system will continue to oscillate back and forth between the saturated regions. This can happen even in systems that are quite stable once synchronized.

There are several methods in use for effecting satisfactory synchronizing in high-gain servos (see note on page 106). A new circuit will be described here which does not require relays or major modifications to the primary circuits of an existing system. The new synchronizing circuit operates to:

1) sense that the load is considerably out of correspondence with the system's reference input, and

2) as the load approaches correspondence at high speed, produce a voltage pulse of proper amplitude and phase to bring the load into correspondence at the maximum allowable deceleration.

Form of synchronizing pulse

The purpose and operation of the synchronizing circuit are best explained by considering its application to a particular system. The maximum permissible or obtainable speed and acceleration of the load must be considered to determine the various parameters of the synchronizing circuit, such as the angular error at which the synchronizing pulse is initiated, the time-constants for the pulse-forming circuits, and the amplification required to produce a pulse of sufficient amplitude.

For explanation, assume that the power drive portion of a servomechanism to be synchronized is the Ward-Leonard system shown in Figure 2. The output voltage of the dc generator, e_g, is varied to produce changes in the speed of the dc motor, causing the motor to assume the output position θ_o. Signals applied to the grids of the electronic dc amplifier vary the currents in the push-pull fields of the generator. The net generator field current is propor-

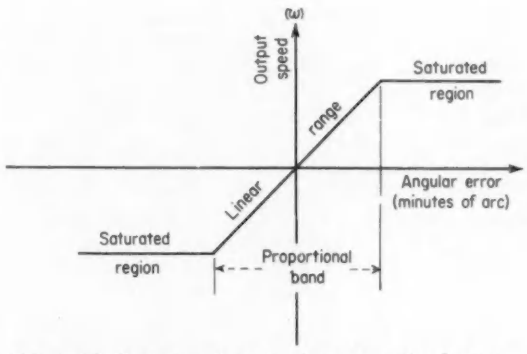


FIG. 1. Idealized saturation curve for a proportional servo.

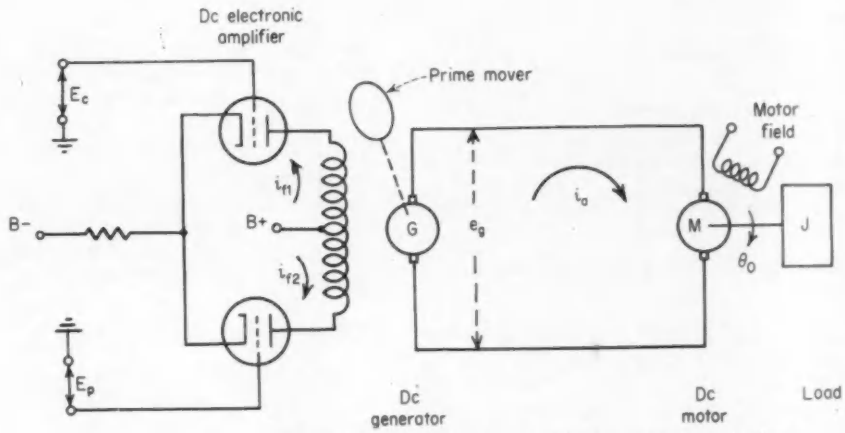


FIG. 2. Ward-Leonard power drive system for which the synchronizing pulse is derived to illustrate the technique.

tional to the difference in the two signals E_c and E_p, where E_c is the usual control signal and E_p is the synchronizing pulse. Assume that, under normal linear tracking operation, E_p is either so small as to be negligible or is blocked by biased diodes.

Neglecting friction in the motor and load, and inductance in the motor and generator armature circuits and in the generator fields, the differential equation for the system of Figure 2 can be written as

$$E_c - E_p = K_2 \frac{d^2\,\theta_o}{dt^2} + K_1 \frac{d\,\theta_o}{dt} \qquad (1)$$

Under idealized operating conditions, the load will be moving at maximum angular velocity until the instant the synchronizing pulse is initiated. From that time until correspondence is reached the load decelerates uniformly at its maximum rate. This idealized velocity-time characteristic (Figure 3) will give the system its optimum response. During the synchronizing interval, the acceleration is given by the expression:

$$\alpha_o = \frac{d^2\,\theta_o}{dt^2} = -\frac{\omega_{o\,max}}{T_1} = \alpha_{o\,max}, \text{ a constant} \qquad (2)$$

which defines T_1.

The velocity is given by

$$\omega_o = \frac{d\,\theta_o}{dt} = \omega_{o\,max} + \alpha_{o\,max}\,t \qquad (3)$$

The angular output position at any instant during the synchronizing interval is given by

$$\theta_o = 1/2\;\alpha_{o\,max}\,(T_1^2 - t^2) \qquad (4)$$

It is assumed here that θ_o is measured from the position of correspondence and that θ_i is constant at zero. θ_o is thus equal to the angular error. At $t = 0$,

$$\theta_o = 1/2\;\omega_{o\,max}\,T_1 \qquad (5)$$

which is the angular error at which the synchronizing pulse should be initiated.

Within the limitations of the assumptions made, a more specific expression can now be developed for the voltage to be applied to the amplifier of Figure 2. Substituting Equations 2 and 3 into 1,

$$E_e - E_p = K_1\,\omega_{o\,max} + \alpha_{o\,max}\,(K_2 + K_1\,t) \qquad (6)$$

Assume here that the control voltage, E_c remains constant throughout the entire synchronizing interval. This is true in most high-gain systems due to saturation in the stages preceding the dc amplifier or due to the operation of signal or velocity limit circuits. Of course, E_c will start to decrease at a point very close to correspondence, but this occurs too late to influence the synchronizing action. It is this very fact which dictates the need for the synchronizing circuit. Under these assumptions

$$E_c = K_1\,\omega_{o\,max} \qquad (7)$$

and Equation 6 reduces to

$$E_p = -\alpha_{o\,max}\,(K_2 + K_1\,t), \text{ for } 0 \gtrless t \gtrless T_1 \qquad (8)$$

This pulse shape is shown in Figure 4.

A practical circuit

A considerable amount of variation is possible in the details of the circuitry used to produce the synchronizing pulse. The circuit of Figure 5 was used

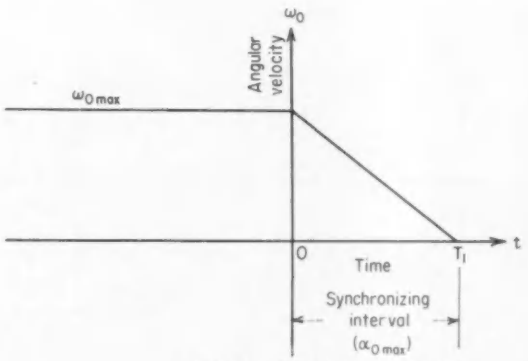


FIG. 3. Idealized velocity-time curve for synchronizing a position servo.

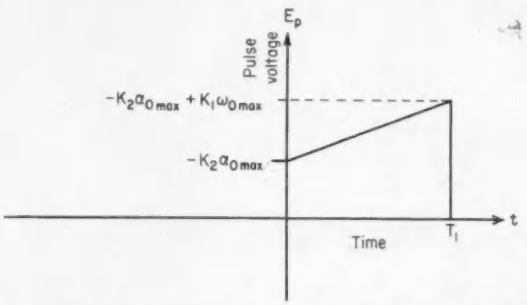


FIG. 4. Idealized synchronizing pulse for the system of Figure 2.

successfully by the authors, for, although it does not produce the pulse shape of Figure 4, it does produce an exponential pulse of arbitrarily large amplitude that endures long enough to ensure proper synchronization. The circuit worked well because the system to which it was applied used limit circuits that operated to limit the magnitude of E_c, and thus, the speed and acceleration of the load. In this system, it was possible to produce a close approximation to the response of Figure 3 due to the combined effect of E_c and E_p.

The circuit of Figure 5 operates as follows. An ac position error signal from a synchro data system or other source is applied to a half-wave phase sensitive detector. The amplitude of the applied error signal is proportional to the actual angular error. The detector converts the error signal to a dc voltage E_s. The polarity of E_s depends on whether the error signal voltage, e_s, is in phase or 180 deg out of phase with the reference voltage, e_r. For small angular errors, E_s is proportional to the error voltage. For angular errors which make e_s greater than e_r, the phase sensitive detector will saturate and E_s will remain constant at its maximum level. As the load moves toward correspondence at its maximum speed and the angular error is reduced to the point where $e_s = e_r$, E_s starts to decrease. E_s is differentiated by the network of C_2 and R_3 to produce the voltage pulse E_p.

The magnitude of the reference voltage determines the angular error at which the pulse is initiated, and so is an important consideration. The shape and duration of the pulse is determined by the time constants of the differentiating network C_2R_3 and the storage capacitor C_1 in series with R_1, R_2 and the resistors of the twin-T ripple filter. The only effect of the twin-T filter is to remove the ac carrier frequency without affecting the lower frequency data signal that modulates the carrier. C_1 could be omitted if a pulse with a higher amplitude and steeper leading edge is required.

Other pulse circuits

If the system to which the synchronizing circuit is to be applied has no limit circuits, there are other pulse forming techniques which will produce a suitable synchronizing signal. A monostable multivibrator will produce a positive or negative pulse that is nearly flat-topped. If the initial and final values of E_p were calculated for a given application to be nearly the same, the square shaped pulse could be used directly. The amplitude and duration of such a pulse are easily controlled.

A more elaborate circuit, known as a monostable screen-coupled phantastron[2], is capable of delivering a voltage pulse having a linearly sloping leading edge and an exponentially decaying trailing edge. By making the time constants which affect the trailing edge fairly small, this circuit could be used to produce almost the exact pulse shape of Figure 4.

NOTE: If a synchro data system is used, a small proportional band implies fairly high precision, hence a fine-coarse system. A relay can be used to switch from the fine to the coarse synchro[3], and other contacts on this relay could also be used to simultaneously broaden the proportional band, i.e., reduce the gain. The relay could also introduce special compensating networks.

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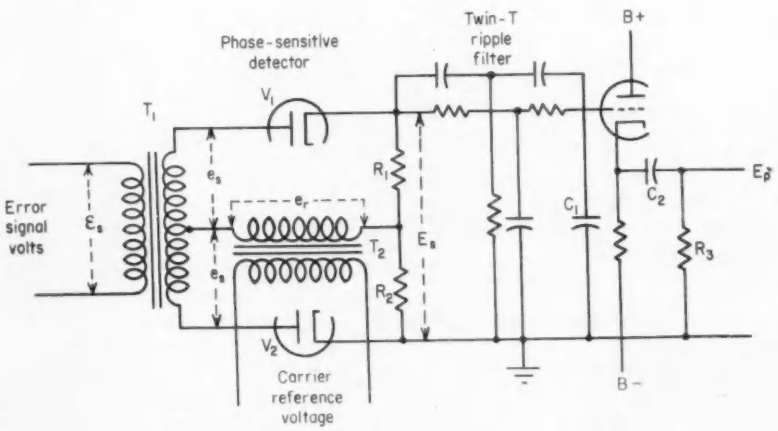


FIG. 5. Practical pulse-forming circuit when system has velocity limit circuits.

KEY FACTORS IN SELECTING TRANSISTORIZED REGULATORS

MICHEL MAMON, Control Instrument Co.

This set of tables shows the equivalent circuits of existing transistorized voltage and current regulator designs. It states the expressions derived from the equivalent circuits for the output impedance and the voltage stabilization factor: two figures of merit with which the control engineer can compare the alternate designs for specific applications. The voltage stabilization factor rates the effectiveness with which each regulator reduces ripple and supply fluctuation.

In accordance with customary symbols:

α = common-base current gain
β = common-emitter current gain
r_e = emitter resistance
r_b = base resistance
r_c = collector resistance

In the analysis of these circuits the following assumptions were made:

$$\beta = \frac{\alpha}{1-\alpha} >> 1,$$

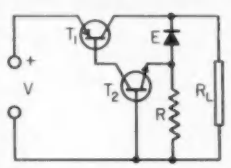
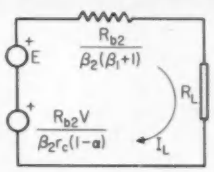
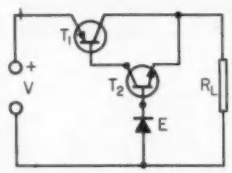
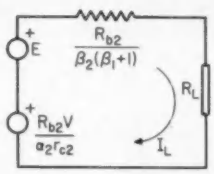
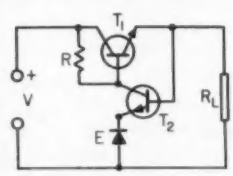
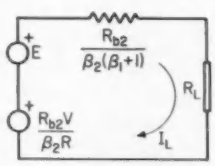
$$r_{c1}(1-\alpha_1) \cong r_{cn}(1-\alpha_n) = r_c(1-\alpha)$$
$$r_c(1-\alpha) >> R_{L},$$
$$R_b << r_c(1-\alpha),$$

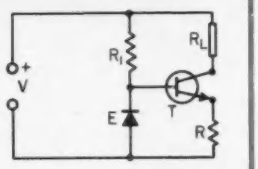
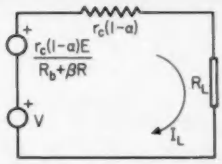
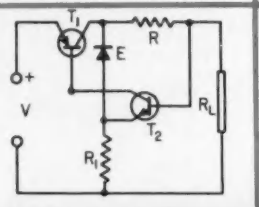
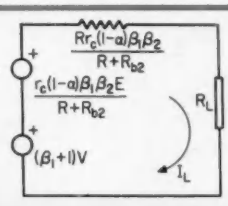
where $R_b = r_b + \beta r_e$

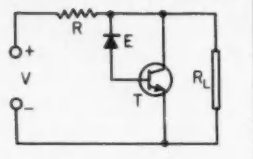
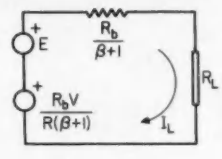
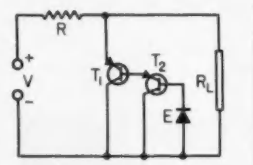
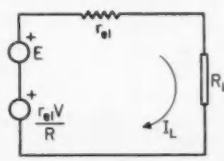
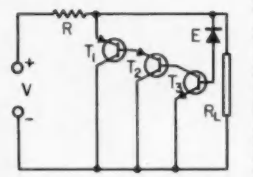
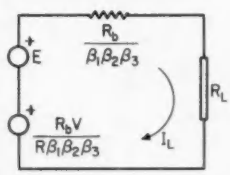
and the dynamic impedance of the reference diode is negligible or lumped with R_b.

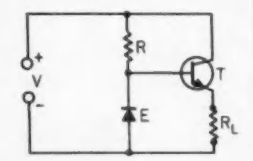
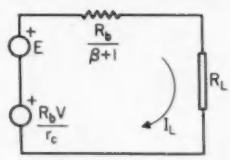
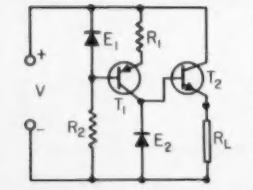
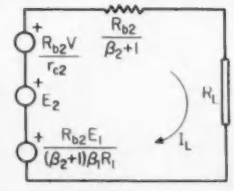
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SERIES–FEEDBACK VOLTAGE REGULATORS	EQUIVALENT CIRCUIT	OUTPUT IMPEDANCE	VOLTAGE STABILIZATION FACTOR $\frac{\Delta E_O}{\Delta V}$
		$\frac{R_{b2}}{\beta_2(\beta_1+1)}$	$\frac{1}{\alpha_2 r_{c2}\left[\frac{1}{R_{b2}}+\frac{1}{\beta_2(\beta_1+1)R_L}\right]}$
		$\frac{R_{b2}}{\beta_2(\beta_1+1)}$	$\frac{1}{\alpha_2 r_{c2}\left[\frac{1}{R_{b2}}+\frac{1}{\beta_2(\beta_1+1)R_L}\right]}$
		$\frac{R_{b2}}{\beta_2(\beta_1+1)}$	$\frac{1}{R\left[\frac{\beta_2}{R_{b2}}+\frac{1}{(\beta_1+1)R_L}\right]}$

CURRENT REGULATORS	EQUIVALENT CIRCUIT	OUTPUT IMPEDANCE	CURRENT STABILIZATION FACTOR
		$r_c(1-\alpha)$	$\frac{1}{r_c(1-\alpha)+R_L}$
		$\frac{Rr_c(1-\alpha)\beta_1\beta_2}{R+R_{b2}}$	$\frac{\beta_1+1}{R_L+R_{OUT}}$

SHUNT VOLTAGE REGULATOR	EQUIVALENT CIRCUIT	OUTPUT IMPEDANCE	VOLTAGE STABILIZATION FACTOR $\frac{\Delta E_0}{\Delta V}$
		$\frac{R_b}{\beta+1}$	$\frac{1}{R\left[\frac{\beta+1}{R_b}+\frac{1}{R_L}\right]}$
		r_{el}	$\frac{1}{R\left[\frac{1}{r_{el}}+\frac{1}{R_L}\right]}$
		$\frac{R_{b3}}{\beta_1\beta_2\beta_3}$	$\frac{1}{R\left[\frac{\beta_1\beta_2\beta_3}{R_{b3}}+\frac{1}{R_L}\right]}$

EMITTER FOLLOWER	EQUIVALENT CIRCUIT	OUTPUT IMPEDANCE	VOLTAGE STABILIZATION FACTOR
		$\frac{R_b}{\beta+1}$	$\frac{1}{r_c\left[\frac{1}{R_b}+\frac{1}{(\beta+1)R_L}\right]}$
		$\frac{R_{b2}}{\beta_2+1}$	$\frac{1}{r_{c2}\left[\frac{1}{R_{b2}}+\frac{1}{(\beta_2+1)R_L}\right]}$

A Method of Compensating Loading Errors in Double-Ended Potentiometers

CONTROL ENGINEERING has published a number of articles on methods for compensating loading errors in the output voltage of precision potentiometers. These methods have involved the choice of tap locations and the use of one or more compensating resistors. Author Sandock points out another approach. When either the potentiometer or the reference transformer is center-tapped, he says, loading error can be considerably reduced by a slight increase in the reference voltage. His article shows how to determine the optimum voltage increase factor in such cases.

JULES SANDOCK, Sperry Gyroscope Co.

When potentiometers are used to multiply a shaft position by a reference voltage, the shaft can in some cases be rotated in either direction away from a zero position at the center of the potentiometer. The circuits in Figures 1 and 2 permit phase reversal of the output voltage as the shaft moves past this zero position. In Figure 1, the potentiometer is center-tapped; in Figure 2, the reference transformer is center-tapped. In both circuits the load resistance causes nonlinearity errors in the output voltage. This loading error can be reduced, in each case, by slightly increasing the voltage, $2V_1$, applied to the potentiometer. It will be shown that the error reduction obtained in the center-tapped potentiometer circuit is approximately twice that which can be obtained in the center-tapped transformer circuit. The table at right lists preliminary definitions and equations.

Assuming that the output impedance of the transformer and associated trimmer resistance are negligible compared to the potentiometer resistance, the output impedance, R_o, can be determined as a function of the shaft position.

Center-tapped potentiometer

The circuit shown in Figure 1 has been redrawn in Figure 3 to illustrate the derivation of R_o as a function of X. Here the trimmer pot is ignored and the voltage source shorted out. The total resistance between the terminals before loading equals $\frac{1}{2}X$ ohm in parallel with $(1 - \frac{1}{2}X)$ ohm. This reduces to

DEFINITIONS

Referring to the circuits shown in Figures 1 and 2:

V_{2d} = desired output voltage
X = shaft position (nondimensional fraction of plus or minus 1)
V_R = desired reference voltage
$2V_1$ = voltage across potentiometer
K = compensation or voltage increase factor
V_2 = actual output voltage
R_o = output impedance of potentiometer (normalized to 1 ohm)
V_e = output voltage error

a = load ratio = $\dfrac{\text{actual load resistance}}{\text{total pot resistance}}$

(numerically equal to load resistance in this case)

ϵ = output voltage error for normalized reference voltage, V_R

EQUATIONS

Based on the above definitions, the following equations maintain:

$$V_{2d} = X \cdot V_R \tag{1}$$

$$V_1 = V_R(1 + K) \tag{2}$$

$$V_2 = X \cdot V_1 \frac{a}{a + R_o} \tag{3}$$

$$V_e = V_{2d} - V_2$$

$$V_e = X \cdot V_R - X \cdot V_R(1 + K) \frac{a}{a + R_o}$$

$$V_e = \frac{XV_R}{a + R_o}(R_o - Ka) \tag{4}$$

$$\epsilon = \frac{V_e}{V_R} = \frac{X}{a + R_o}(R_o - Ka) \tag{5}$$

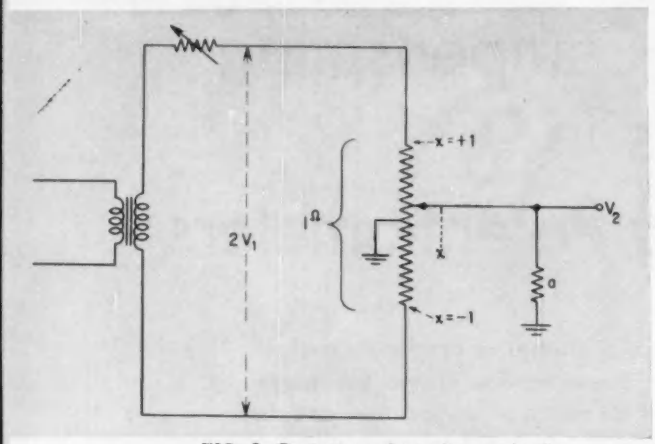


FIG. 2. Center-tapped transformer circuit.

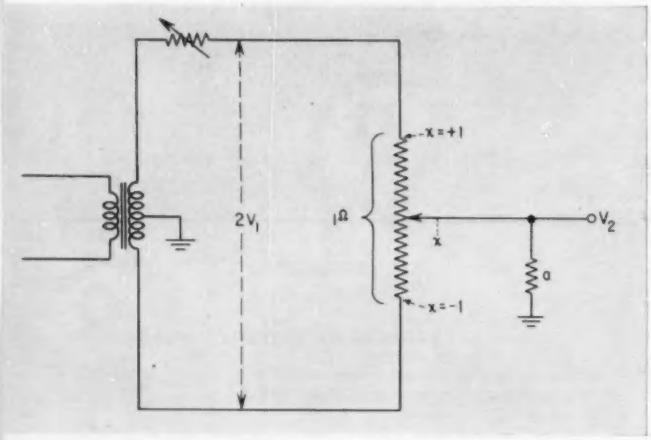


FIG. 1. Center-tapped potentiometer circuit.

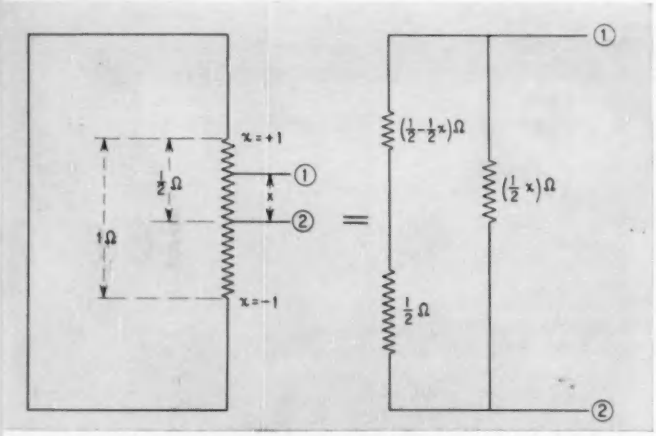


FIG. 3. Circuit for determining output impedance.

$$R_o = \frac{X(2-X)}{4} \quad \text{where} \quad 0 \le X \le 1 \tag{6}$$

Substituting this value at only one point in Equation 5 yields

$$\epsilon = \frac{X}{a + R_o}\left[\frac{X(2-X)}{4} - Ka\right]$$

or $$(a + R_o)\epsilon = -\frac{X^3}{4} + \frac{X^2}{2} - KaX,$$

and since $R_o \ll a$, $$a\epsilon = -\frac{X^3}{4} + \frac{X^2}{2} - KaX \tag{7}$$

Figure 4 shows how the loading error, $a\epsilon$, varies with positive shaft positions for $Ka = 0$ (no compensation), 0.17, 0.22, and 0.28. Since only the sign changes for negative shaft positions, these results are not plotted here. It can be seen that with no compensation ($Ka = 0$), the loading error is greatest at $X = 1$. As Ka is increased, $a\epsilon(+1)$ decreases, but the loading curve develops an internal maximum, $a\epsilon_m$. The optimum value of Ka then is a matter of compromise between $a\epsilon_m$ and $a\epsilon(+1)$.

To determine this optimum value of Ka, it is necessary to plot two curves as shown in Figure 5. The solid line indicates the loading error at $X = 1$, as the compensation changes, while the broken line indicates the corresponding change in the maximum internal error. Optimum compensation is established at $Ka = 0.222$. Here neither $a\epsilon_m$ nor $a\epsilon(+1)$ exceeds 0.029. This is approximately an 8 to 1 reduction compared to the uncompensated case.

Center-tapped transformer

If the center-tapped transformer circuit (Figure 2) is reduced to equivalent resistances, as was the potentiometer circuit, then again neglecting any impedance in the trimmer pot and transformer, the output impedence, R_o, for any shaft position, X, will be equivalent to $(\frac{1}{2} - \frac{1}{2}X)$ ohm in parallel with $(\frac{1}{2} + \frac{1}{2}X)$ ohm, that is

$$R_o = \frac{1 - X^2}{4}, \tag{8}$$

and therefore $$a\epsilon = \tfrac{1}{4}X - \tfrac{1}{4}X^3 - KaX \tag{9}$$

The curves shown in Figure 6 are obtained by using compensations $Ka = 0$, 0.02, 0.06, and 0.08. Notice that when $Ka = 0$, the loading error is greatest at some point between $X = 0$ and $X = 1$. As Ka increases, this internal maximum, $a\epsilon_m$, decreases, but the loading error, $a\epsilon(+1)$, becomes appreciable. The optimum value of Ka is again a matter of compromise between the loading error at $X = 1$, and the maximum internal loading error. Figure 7 shows how $a\epsilon(+1)$ and $a\epsilon_m$ depend on compensation. With optimum compensation ($Ka = 0.063$), neither $a\epsilon(+1)$ nor $a\epsilon_m$ exceeds 0.0625. This error is approximately twice as great as that obtained in the center-tapped potentiometer circuit.

The only analytical approximation in the above derivation is

$$a \cong (a + R_o) \tag{10}$$

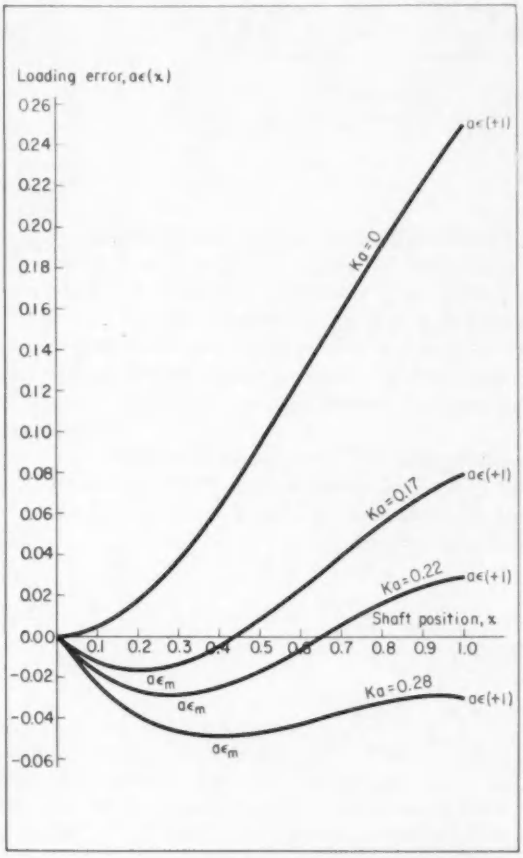


FIG. 4. Loading error vs. shaft position—center-tapped potentiometer.

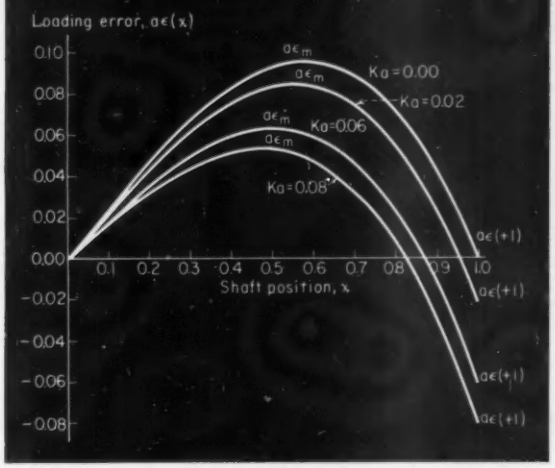


FIG. 6. Loading error vs. shaft position—center-tapped transformer.

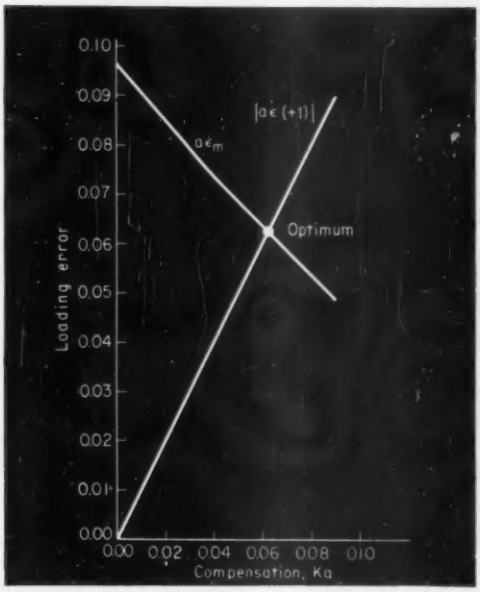


FIG. 7. Loading error vs. compensation—center-tapped transformer.

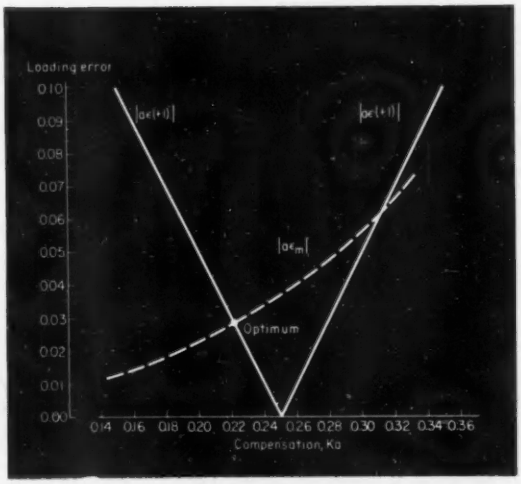


FIG. 5. Loading error vs. compensation—center-tapped potentiometer.

which is implicit in Equations 7 and 9. However, this is a conservative approximation because the true loading errors would actually be smaller than those computed with the approximate equations, and plotted in Figures 4 and 7. The amount of inaccuracy introduced by this approximation is no greater than $\frac{1}{4}a$ times the computed values. In most practical cases, this is negligible.

Due to certain tolerances on Ka, it is often difficult to achieve optimum compensation. These tolerances may arise from limitations on the accuracy with which the voltage, $2V_1$, can be measured and adjusted, or from variations in the load ratio, a, due to variations in the potentiometer resistance and load resistance. Figures 5 and 7 can be used to determine the effect of these tolerances.

MEASURING MASS FLOW
with the boundary-layer flowmeter

The electrocaloric flowmeter of the boundary-layer type features an essentially linear scale over a major portion of its range, is impervious to chemical attack when constructed with the proper materials, and uses a smooth-bore flow transmitter which introduces a negligible pressure drop. It also has no leakage or sealing problems, requires little maintenance or cleaning, and is simple to install in the process piping. All these characteristics make the flowmeter particularly advantageous in measuring and controlling mass-flow rate.

The author describes the underlying theory of the boundary-layer flowmeter, the considerations involved in designing and constructing a practical flowmeter, and the application of the flowmeter in closed-loop control systems using either electric or pneumatic actuators.

J. H. LAUB, Industrial Development Laboratories, Inc.

When fluid flows in a conduit a thin film of fluid particles forms on the conduit's inside surface. This film, partly adhering to the surface and partly in laminar flow parallel to the surface, is called a boundary layer. The amount of heat required to develop a known temperature difference across the boundary layer indicates the heat transfer rate, and this rate through the boundary layer is a measure of the fluid's mass-flow rate. Thus, the heat injected becomes a measure of the mass-flow rate.

A practical design of a flowmeter based on the boundary-layer principle is shown in Figure 1. Essentially, the flowmeter consists of an electric heating coil wound around the outside of the pipe and two resistance temperature detectors (which feed into a Wheatstone bridge) also wrapped around the outside of the pipe—one upstream from the heater coil and the other downstream. The amount of power (watts dissipated in the heater coil) supplied to the fluid to maintain a constant temperature difference between the two temperature detectors indicates the mass-flow rate.

BOUNDARY-LAYER PRINCIPLE

Heat flowing radially inward from the heater coil in Figure 1 meets the following obstacles in its path: a thin layer of insulation between the heater coil and the conduit's outside surface, the wall of the conduit, the boundary layer, and the main core of the fluid. Radial heat transfer through the boundary layer takes place by conduction, since there is no interchange of fluid particles with the main core. If the main core is in turbulent flow the transition from laminar to turbulent motion occurs in an intermediary buffer layer. Here eddy currents develop, resulting in radial motion of fluid particles and heat transfer by convection. Thickness of the boundary layer varies with velocity of the fluid stream, [1,2,3].

Under turbulent-flow conditions the boundary layer is the main barrier to heat transfer and thus requires the major share of the temperature difference between the heat source and the center of the conduit. Figure 2 shows the radial temperature distribution in the conduit. The solid line characterizes the conditions of turbulent flow (Reynolds numbers greater than 2,100). At flow velocities in the laminar range (Reynolds numbers less than 2,100) the temperature decreases more gradually from the wall to the conduit axis (dashed line).

Heat transfer rate

If a quantity Q of heat is transferred through an area A of thermal transmittance U, a temperature gradient Δt results:

$$Q = UA\,\Delta t \qquad (1)$$

Here the temperature gradient Δt represents the total of the temperature gradients across all barriers to heat flow. Normally in a boundary-layer flowmeter of the type shown in Figure 1, all temperature gradients, except that across the boundary-layer, will be negligible. For the sake of completeness, however, the temperature gradient across the conduit wall as well as that across the boundary layer are included in the following analysis:

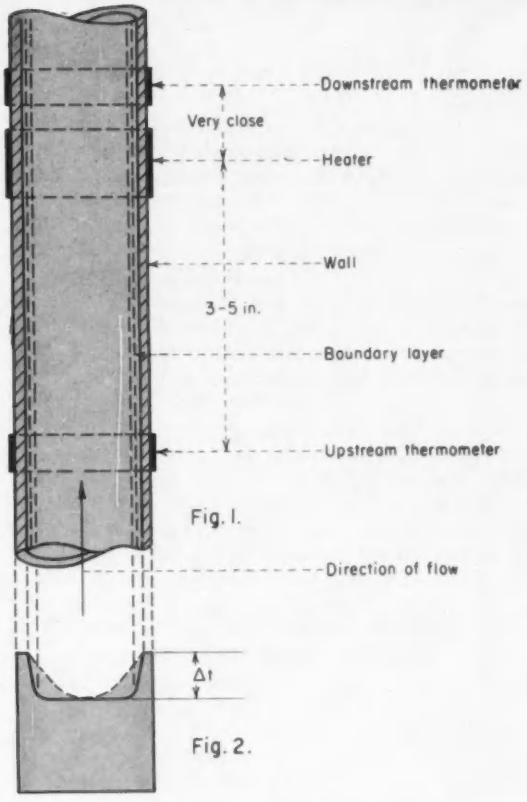


Fig. 1.

Fig. 2.

FIG. 1. In a well-designed boundary-layer flow transmitter of the type shown here, the amount of power injected into the fluid by the heater coil to maintain a known temperature difference between the upstream and downstream thermometers indicates the mass flow rate of the fluid.

FIG. 2. The radial temperature distribution through the core of the fluid depends on whether the flow is turbulent or laminar. For turbulent flow the major temperature drop is across the boundary layer (solid line), but for laminar flow conduction between fluid particles causes the temperature gradient to change gradually toward the center of the fluid core.

The transfer of Q through the wall requires a temperature gradient Δt_w:

$$Q = k_w A \, \Delta t_w \tag{2}$$

where k_w is the wall's thermal conductance. The transfer of Q through the boundary layer requires a temperature differential Δt_b which can be calculated from:

$$Q = hA \, \Delta t_b \tag{3}$$

where h is the film conductance of the boundary layer.

The total temperature difference Δt is the sum of Δt_w and Δt_b:

$$\Delta t = \Delta t_w + \Delta t_b = \frac{Q}{A}\left(\frac{1}{k_w} + \frac{1}{h}\right) \tag{4}$$

Thus:

$$Q = A \, \Delta t \frac{1}{\frac{1}{k_w} + \frac{1}{h}} = C \frac{k_w h}{h + k_w} \tag{5}$$

Equation 5 describes how Q varies with h for a given wall conductance k_w if Δt is held constant. When the conduit walls are thin and have high thermal conductivity k_w becomes much larger than h and Equation 5 simplifies to:

$$Q = A \, \Delta t \, h \tag{6}$$

The film conductance h is a function of the mass rate of flow, the properties of the fluid, and the dimensions of the conduit. Reynolds first established the relationship between the various parameters by applying the analogy between heat transfer and momentum transfer in a fluid. The results, later confirmed by dimensional analysis, can be written in the form known as Nusselt's expression:

$$Nu = C(Re)^p \times (Pr)^q \tag{7}$$

in which Nu is the Nusselt number, Re is the Reynolds number, and Pr is the Prandtl number of the fluid. These numbers are defined as follows:

$$Nu = hD/k \tag{8}$$

$$Re = DV\delta/\mu = DG/\mu \tag{9}$$

$$Pr = c\,\mu/k \tag{10}$$

where D is the conduit's inner diameter
k is the fluid's thermal conductivity
c is the fluid's specific heat
μ is the fluid's absolute viscosity
δ is the fluid's density
V is the fluid's average velocity
G is the fluid's average velocity $\times$ mass density $= V\delta$

For turbulent conditions (Re greater than 2,100) close agreement between experimental results and the Nusselt equations is obtained with $C = 0.023$; $p = 0.80$; and $q = 0.40$. Equation 7 then becomes[4]:

$$\frac{hD}{k} = 0.023\left(\frac{DV\,\delta}{\mu}\right)^{0.8}\left(\frac{c\,\mu}{k}\right)^{0.4} \tag{11}$$

which can be written:

$$h = 0.023\,\frac{k^{0.6}\,c^{0.4}}{D^{0.2}\,\mu^{0.4}}\,G^{0.8} \tag{12}$$

Equation 12 applies to the entire range of turbulent flow, except for viscous liquids where it is valid only for Re greater than 10,000. This equation satisfies practically the entire range of a flowmeter for low-viscosity fluids, since a Reynolds number of 2,100 corresponds to approximately 2 percent of the maximum flow-rate in an actual design.

For flow velocities less than Re = 2,100 the flow is laminar. Under these conditions the film conductance can be expressed by the empirical formula[5]:

$$h = 2.34\,\frac{k^{2/3}\,c^{1/3}}{(DL)^{1/3}}\,G^{1/3} \tag{13}$$

where L is the length of the heated surface.

For zero flow (Re equals zero) the film conductance is so small for most fluids, compared with the conduit wall's longitudinal conductance, that it can be neglected. The longitudinal conductance is deter-

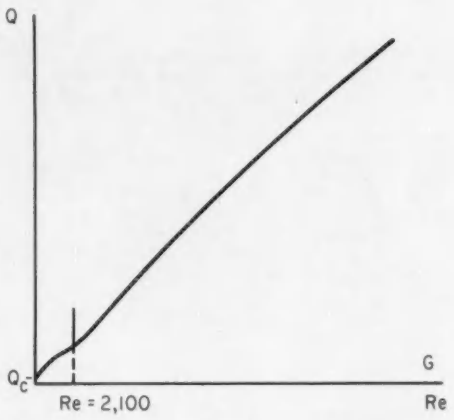


FIG. 3. Over the major portion of the flowmeter range the amount of heat input varies almost linearly with the product of the average mass velocity and density (G), where G is proportional to the mass flow rate F, lb/hr.

mined by the wall's annular area and thermal conductivity and the spacing of the temperature detectors from the heater.

Equations 12 and 13 show the dependence of film conductance h on G, the product of the fluid's average velocity and mass density. But the mass flow rate F, in which terms the flowmeter is actually calibrated, equals G times the cross-sectional area of the conduit.

Heat input vs. mass-flow rate

The relationship between heat input (Q Btu) and G (hence F) can now be found over the entire range of mass-flow rates by inserting the values of h obtained for the three flow-rate conditions in Equation 6. If Δt is held constant Q is proportional to h. For a given stream composition (k, c, and μ constant) and a given design (D constant) Equation 12 (for the turbulent range) shows that Q varies with the 0.8 power of G. For the laminar range Equation 13 shows that Q varies with the $\frac{1}{3}$ power of G. For zero flow Q assumes a (small) value determined by the parameters of the conduit.

Figure 3 shows graphically how the heat input varies over the entire flow-rate range. For zero flow the heat input is a minimum-value Q_c determined by the conduit's parameters. In the laminar region the slope corresponds to a cube root relationship. In the turbulent range (that is, almost the entire flowmeter range) the plot is practically linear.

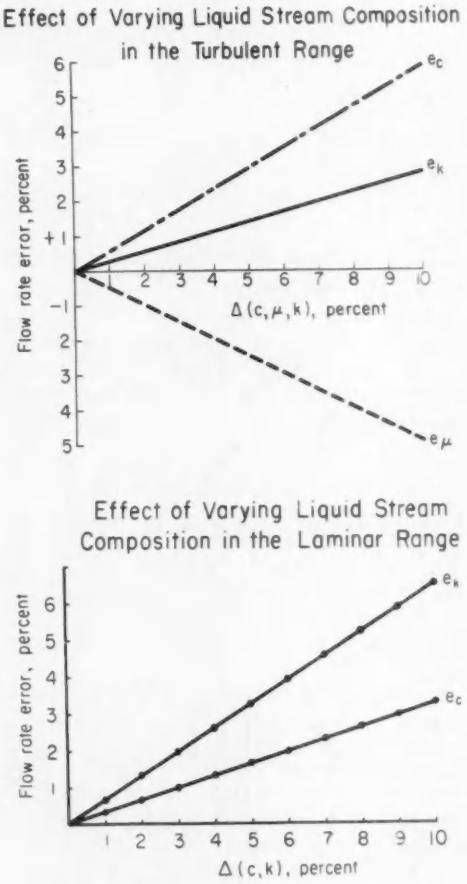
Stream composition and temperature

The preceding discussion covered the effect of varying flow rate on the heat transfer through the boundary layer, showing how a measurement of the temperature differential across the boundary layer can indicate the flow rate. Other factors, such as variations of the stream composition and fluid temperature, affect the heat transfer, too, and thus would produce flow rate errors unless accounted for.

In some applications of the boundary-layer mass flowmeter the stream composition will vary, even with a constant temperature, within certain limits and the fluid parameters k, c, and μ, appearing in the Prandtl number, will not remain constant. Equations 12 and 13 show how these variations affect the film conductance of the boundary layer in the turbulant and laminar range, and Equation 6 reveals the resulting effect on Q when Δt is held constant.

For gas streams the Prandtl number is very nearly independent of the composition, and flow-rate errors due to variations in this factor thus become negligible.

Composition variations of liquid streams introduce flow-rate errors, the magnitude of which can be determined for the turbulent and laminar regions. Errors in the turbulent range, according to Equation 12 and 6, are proportional to the 0.4th power of c,



FIGS. 4 and 5. Stream composition variations (changes in specific heat, c, thermal conductivity k, and viscosity μ) appear as errors in flow-rate indication in the turbulent range (Figure 4). The percentage error is less than proportional to the change in the variable. For laminar flow, Figure 5, only variations in c and k introduce errors.

so that a 5-percent change in the specific heat results in less than a 2-percent error in flow-rate indication. Since the error is inversely proportional to the 0.4th power of μ, the error will be reduced or will become zero if both specific heat and viscosity increase or decrease together. A change in the stream composition ordinarily has little effect on the thermal conductivity k of a liquid, but if any change in k does occur the resulting error in flow-rate indication is less than proportional to the variation in k. This is true for both laminar and turbulent flow, as shown in Figures 4 and 5.

In the laminar range, Equation 13 shows that variations of c have little effect on the flow-rate indication since h is proportional to the cube root of c. Variations of μ need not be considered in the laminar range because this parameter does not influence the film conductance h, as can be seen from Equation 13.

In a stream of fixed composition c, k, and μ will also normally change with a variation in stream temperature. The effect may be substantial for liquids, but negligible for gases. The effect of stream temperature variations can be assayed by determining the change in c, k, and μ over the expected temperature variation, and the resulting change in h from Equations 6, 12, and 13. Since temperature variations may be considerable, temperature compensation must be included in the flowmeter design for liquids to minimize indicated errors of flow rate. The compensation is easily accomplished in the bridge circuit by winding a temperature-sensitive resistance around the pipe and connecting this resistance in series with one of the fixed resistors in the bridge[6]. In this way the bridge responds only to variations of flow rate and not of temperature.

DESIGNING A FLOW-RATE TRANSDUCER

In theory, implementation of the boundary-layer principle as a mass-flow measuring method requires temperature measurements on both sides of the boundary layer to obtain Δt. But this is impractical on several counts: the boundary layer is only several thousandths of an inch thick and varies in thickness with the fluid and Reynolds number; thus one fixed position of the internal temperature detector would not satisfy all possible conditions. Also, a temperature detector located inside the pipe becomes subject to corrosive influences, obstructs the flow, increases pressure drop, can be attacked by fluid and solid particles, and introduces a sealing problem.

In practice, both temperature detectors for measuring Δt are located outside the pipe, as shown in Figure 1. With proper design, this arrangement measures the Δt across the boundary layer, as can be seen from the following analysis: the upstream thermometer, located about 3-5 in. away from the heater coil, is unaffected by the heat injected into the stream by the heater coil and thus the thermometer can be assumed to be measuring the inside temperature of the boundary layer. The heat injected into the stream by the heater coil raises the temperature of the pipe wall which, because of its small thermal resistance, is essentially the same temperature as the outside of the boundary layer. This temperature is measured by the thermometer immediately downstream from the heater coil. Thus the inside of the heater coil, the pipe wall near the heater coil, and the outside of the boundary layer are all considered as being at the same temperature, Δt higher than the temperature inside the boundary layer.

Calculating the power input

The quantity actually measured in the flowmeter is not Q, but the wattage W dissipated in the heater coil and measured by a wattmeter. Thus a wattmeter, calibrated in terms of mass flow, serves as the indicating instrument for the boundary-layer mass flowmeter.

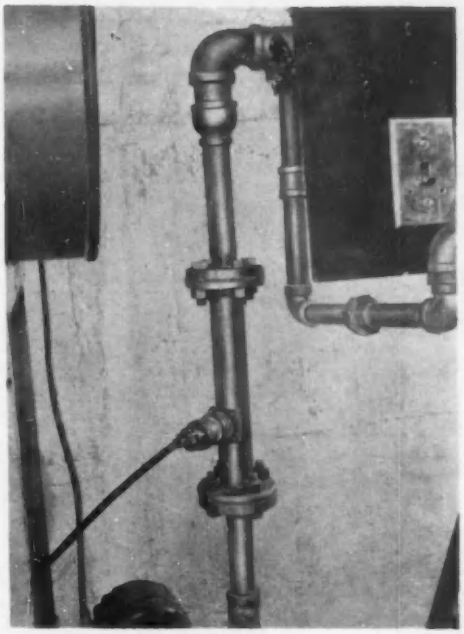


FIG. 6. The boundary-layer mass flow transmitter shown here is steel-jacketed to protect it against external damage and to hermetically seal the measuring elements. The AN-type electrical connector assures correct connection of leads to the indicating and control instruments.

The heat transfer to the fluid as a function of the rate of fluid flow in the turbulent and laminar range can be calculated from Equations 6, 12, and 13 if the fluid properties are known. The maximum heat flow Q_m, which corresponds to the maximum flow-rate of a flowmeter of given design, can thus be readily determined.

A flowmeter with a maximum mass-flow rate F of 12,000 lb/hr of water in a conduit of 1½ in. in diam

serves as a design example. Here $F = G$ times area of conduit. The parameters to be inserted into Equation 12 are:

$D = 0.125$ ft
$k = 0.364$ Btu/hr (sq ft) (deg F/ft)
$c = 0.997$ Btu/lb/deg F
$\mu = 1.65$ lb/(ft) (hr)
$\delta = 61.99$ lb/cu ft
$V = 15{,}770$ ft/hr
$G = 976{,}000$ lb/sq ft hr
$Re = 74{,}000$
$Pr = 4.51$

This yields a maximum value of the film conductance h.

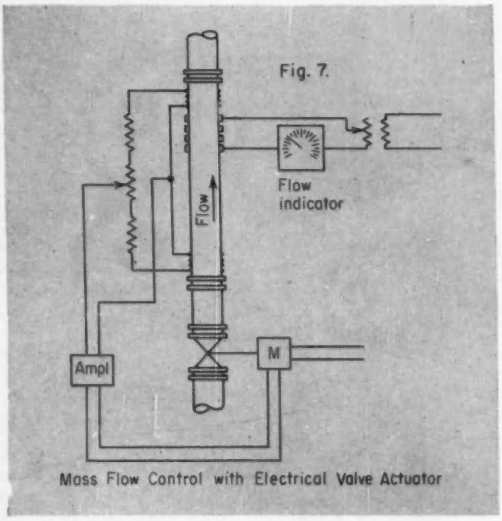
$$h_m = 0.023 \frac{0.364^{0.6} \times 0.997^{0.4}}{0.125^{0.2} \times 1.65^{0.4}} 976{,}000^{0.8}$$

$$= 961 \text{ Btu/hr ft}^2 \text{ deg F}$$

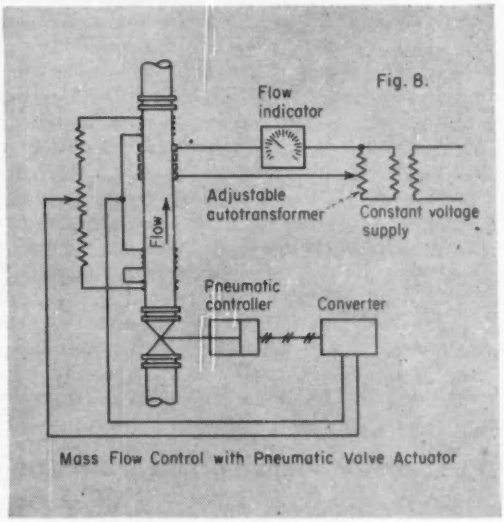
The heater coil of this flowmeter is 2 in. long and has an ID of 1.655 in., resulting in a heat transfer area A equal to 0.0722 ft². If Δt is 2 deg F, Equation 6 yields:

$$Q_m = 961 \times 0.0722 \times 2 = 138.8 \text{ Btu/hr} = 40.8 \text{ watts}$$

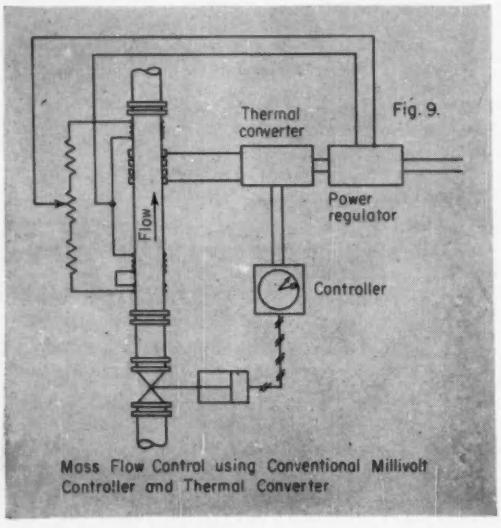
Δt is maintained constant by connecting the two resistance thermometers in a self-balancing Wheatstone-bridge circuit. Automatic adjustment of the heater input power, where the input power indicates the mass-flow rate, is obtained by a servo loop with a motor-driven power regulator or by a purely electronic control circuit which eliminates contacts and mechanically moving parts. In the electronic circuit an unbalance in the bridge caused by a change in flow rate is detected and amplified. The phase of the unbalance signal depends on whether the flow



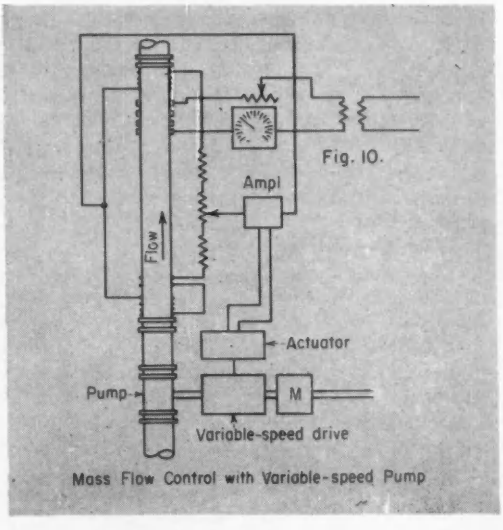
Mass Flow Control with Electrical Valve Actuator



Mass Flow Control with Pneumatic Valve Actuator



Mass Flow Control using Conventional Millivolt Controller and Thermal Converter



Mass Flow Control with Variable-speed Pump

increases or decreases and is discriminated by a triode which controls the charge of a capacitor. The capacitor forms part of an R-C network whose time constant matches that of the thermal analog of the flow-measuring transducer. The voltage across the capacitor controls the firing angle of a pair of push-pull thyratrons which provide smooth regulation of the wattage input to the heater coil. This power supply control circuit is independent of line voltage variations over a wide range.

In designing and constructing a boundary-layer flow transmitter, due consideration must be given the needs of the process fluid while still adhering to the theoretical requirements of the boundary-layer principle. Fluid pressure and corrosive action determine the material and wall thickness of the transmitter conduit. The material should be of high thermal conductance to introduce a small or negligible temperature drop (compared with the temperature drop across the boundary layer) across the conduit's wall. The insulation between the heater coil and temperature detectors and the outside surface of the conduit should be thin and of the highest practical thermal conductivity, again to introduce a small or negligible temperature drop. On the other hand, the outside surfaces of the heater coil and temperature detectors should be well-insulated to assure that all power dissipated in the heater coil goes into the boundary layer and not into the surrounding air. Figure 6 shows a typical boundary-layer mass-flow-rate transmitter installed for an industrial application. Flange connectors permit transmitter removal for cleaning the bore without disturbing the associated piping.

CLOSED-LOOP FLOW CONTROL

Closed-loop control of mass flow rate with the boundary-layer flowmeter is a simple matter for systems using either electrical or pneumatic actuation. Figure 7 shows how proportional control of flow is obtained in processes controlled by an electrically-operated valve. The desired rate of flow is selected by adjusting the wattage input to the heater coil corresponding to the desired rate. Flow-rate indication appears on a calibrated wattmeter in the circuit of the heater coil which is supplied from a constant voltage source. A flow-rate deviation from the desired value produces an unbalance signal in the bridge equivalent to a change from the established Δt. The signal is amplified and fed into the control winding of the motor driving the valve. The valve automatically opens or closes to change the flow until the established Δt, corresponding to the desired flow rate for the fixed wattage input, is restored. For on-off control, in a bypass to a main line, for instance, the unbalance signal drives a solenoid-operated valve.

For pneumatic control, the electrical unbalance signal is converted into a corresponding pneumatic signal for the actuation of the pneumatic-actuated flow control valve. Figure 8 illustrates this method.

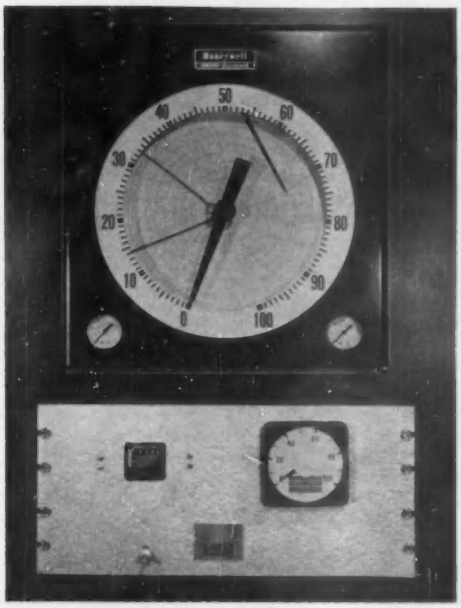


FIG. 11. The electrical signal from the flow transmitter is converted into a pneumatic control signal in a conventional recorder-controller while instantaneous flow rate and total flow appear on the lower panel.

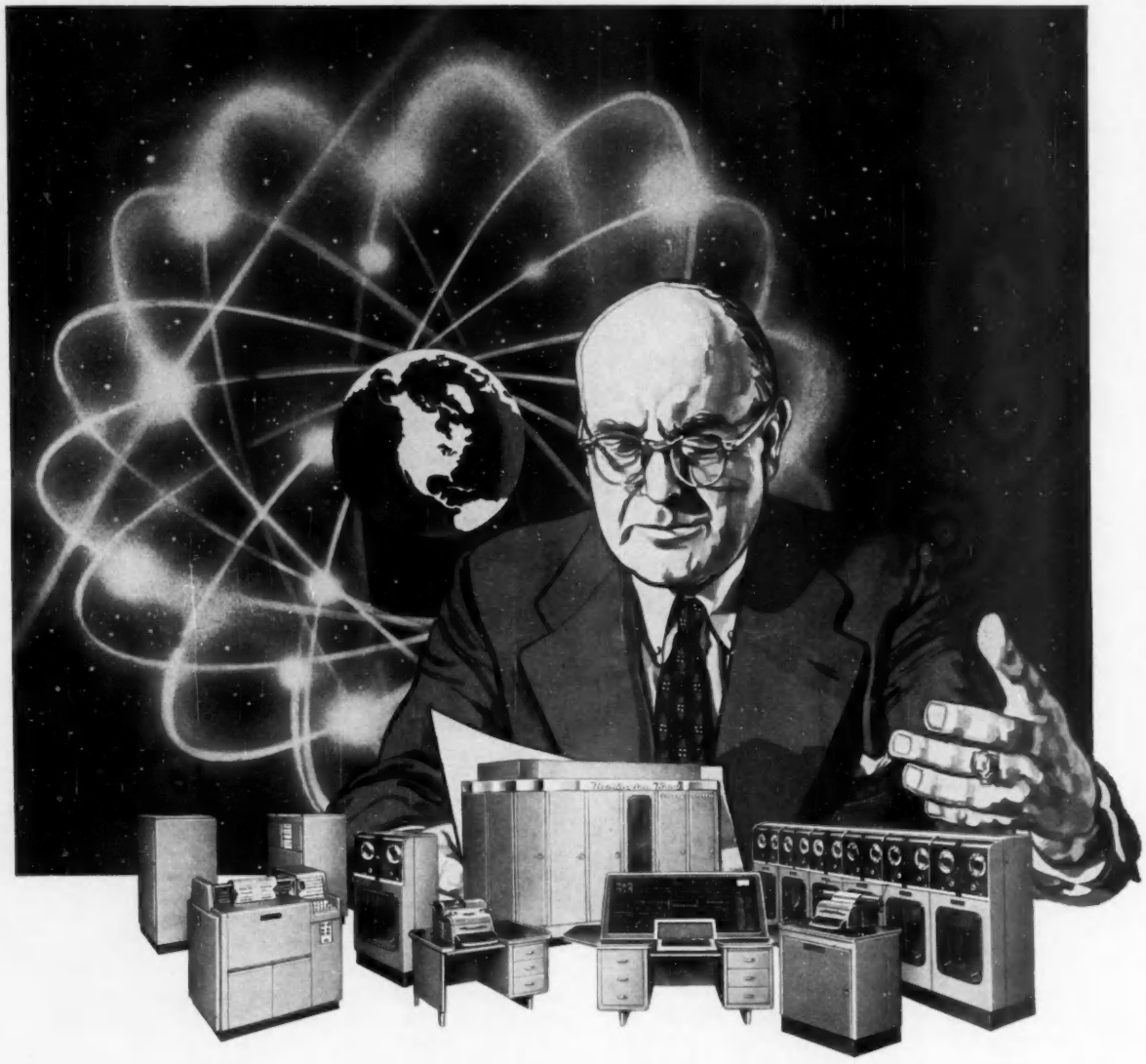
For control systems, Figure 9, employing conventional millivolt recording-controlling instruments with electrical or pneumatic outputs, a thermal converter changes the heater coil input power into a dc voltage which is fed into the self-balancing potentiometer controller. Then the rate of flow is set by the index pointer of the recorder-controller.

In cases where a variable-speed pump controls the flow rate, the unbalance signal is amplified and fed into a reversible motor-actuator which changes the ratio of a variable speed drive to adjust the pump speed. Figure 10 shows this method of controlling the flow from the boundary-layer mass flowmeter.

Figure 11 shows the indicating-recording-controlling section of a flow-measuring installation. (Transmitter installation was illustrated in Figure 7.) The recorder-controller, top, converts the electrical output from the transmitter to a corresponding pneumatic signal. At the bottom left the counter-like device totalizes the flow, while the indicator at the right shows instantaneous flow.

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Programming the Computer

A large amount of preparation is usually required to make effective use of a high-speed computer. This preparation divides into three parts: formulating and analyzing a problem, programming it, and coding the program. In this article all three aspects are covered under "Programming", the basic principles of which are applicable to all classes of problems, whether they are mathematical or scientific, or business data processing, or are those in which the computer serves as the central part of a control system.

SIBYL M. ROCK and WALLACE W. KLAMMER, ElectroData Div., Burroughs Corp.

Any problem to be solved by the computing machine must first be formulated and analyzed, then outlined or flow-charted to display the approach in terms of the general capabilities of computers; this outline must then be translated or "coded", using the "instruction" available in the computer chosen. The program or list of instructions is placed on the physical input medium, so that the relevant data can be read into the internal memory where the computer can work on it and finally produce a report.

The three functions, analysis, programming of the analyzer problems, and coding of the program, may be performed by different individuals or by one person. The distinctions between the functions are apt to overlap, varying from organization to organization and from problem to problem. For this discussion, analysis, programming, and coding will be included under the heading of programming to give a sense of unity to the preparation of a computer problem.

Formulation and analysis of scientific problems

Any problem must be formulated in detail before a program can be devised. In the case of straightforward mathematical problems such as differential equations, sets of linear equations, functions or integrals, and the like, the formulation is well known (among mathematicians)[1] and a usable approach is usually available in textbooks or printed literature. The problems arising from engineering, physics, chemistry, astronomy, and allied sciences are usually of this type.

Once the formulas describing a phenomenon are known, the analyst and programmer must choose a numerical method that meets the needs of his problem so far as accuracy, time required, and the like, are concerned. Much has been accomplished in the field of numerical analysis in the past decade by means of high-speed computers. These machines perform repetitive calculations in so short a time that hundreds of iterative cycles become practicable. Information on convergence, accumulation of round-off errors, and general precision of solutions is being rapidly accumulated, with the result that a usable numerical approach is usually available.

The proper choice of method may reduce running time by a factor of 10 or 100. By one method of evaluating a double integral for many values for example, solution time was about 1/16th as long as by another. A matrix was inverted in four hours one way whereas another approach cut the time to four minutes. A good analyst is an excellent investment.

Where a mathematical approximation is to be used to stimulate a physical situation, the formulation must be completed before the analyst can seek out the best numerical approach. Otherwise, the analyst himself will have to learn much about the physical problem, including its bounds, assumptions, and what is really desired. Construction of the mathematical model will frequently take more effort and time than programming.

Formulation of business and data-handling problems

Formulating most business-data-handling problems almost always takes longer than does mathematical problems. For example, the operation of posting an entry to an inventory account seems very simple indeed—all that is required seems to be to subtract the number of items just used, and replace the total with the new figure. But additional pertinent clerical operations are usually wanted in connection with this same account, and certain other information must be kept about it. These extra items can also be kept by the machine if it is to be used efficiently. The question to be answered might start as follows:

Is there a sufficient amount to cover the request?

If so, make the entry. After the entry, have you reached your stock minimum? If so, set up the name of the vendor and indicate how many to be ordered. If not, go to the next account.

If there was not an adequate stock, indicate how many items can be supplied, and set up for back-order .....etc.

A program can be set up to include almost any combination of clerical operations. However, the user must outline in great detail just what items are to be handled by the computer program, just how he wishes exceptions to be handled, and what his particular company requires for its records. Many procedures now al-

TABLE I

INSTRUCTIONS AVAILABLE IN SIMPLIFIED COMPUTER (ASSUMED)

The symbol xxxx refers to specific memory locations (0 to 3999) used by the instruction.

Arithmetic operations		
1. CAD	xxxx	Clear the *A* register of digits and then add to it the contents of xxxx.
2. AD	xxxx	Add the contents of xxxx to the contents of the *A* register.
3. SU	xxxx	Subtract the contents of xxxx from the contents of the *A* register.
Store results		
4. ST	xxxx	Store the contents of the *A* register in xxxx.
5. STC	xxxx	Store the contents of the *A* register in xxxx. Then clear the *A* register.
Shift to bring digits to correct position in registers		
6. SR	00nn	Shift the contents of the *A* register and the *R* register nn places right.
7. SL	00nn	Shift the contents of the *A* register and the *R* register nn places left.
Branching commands		
8. CNZ	xxxx	Test the contents of the *A* register for zero. If the *A* register setting is not zero, change control to xxxx, otherwise continue sequentially.
Change control		
9. CU	xxxx	Change control so that the next command to be executed will be from xxxx rather than the next one in sequence.
Input-output		
10. PTW	00nn	Print nn digits from the *A* register. Shift left one place for each digit printed.
11. PTR	xxxx	Load data beginning at address xxxx.
Stop		
12. STOP	0000	Stop calculation. Operation may be started again manually.

TABLE II

GENERAL ANALYSIS OR OUTLINE OF A CHECK RECONCILIATION PROBLEM

1. Record the number and amount of each check returned by the bank.
2. Record the number and amount of each check written as shown by the check stubs.
3. Compare the returned check number against the numbers of the written checks.
4. Each returned check number which matches a number on the written check list is removed from the list. The amount is checked against the original entry, and the new balance is computed.
5. If the number is not available, or the amount is incorrect, provide a STOP or other error indication.
6. Retain in a holdover list for the next reconciliation, all written checks not reconciled in Step 4, and add the amount of the check to the check stub balance.
7. After all returned checks have been processed, compare the adjusted stub balance with the bank statement. Stop and signal an error if the two balances do not agree.

low partial computations with desk calculators or electromechanical machines, after which someone must examine account records or reports and use human judgment. Then further machine computation may be used again. Human supervision often depends on the size of a number, on a comparison with other magnitudes, or on whether a number lies within a reasonable range. Such comparisons can be programmed readily—once the full formulation is presented to the programmer. The analyst (or formulator) must search out how the human judgments are made, even where they may seem almost intuitive. Eventually, he must set up the numerical expression for each decision. He may find that many questions considered essential by company A are not considered essential by company B.

These comments appply in general to many problems in the data-handling field—for example, general accounting, payroll, refinery accounting, production control, inventory control, parts explosion, and the like. In general, two features—lack of complete formulation and diversity of information desired—make data-handling problems of this type more difficult to program, as well as to analyze, than the scientific problems. Here it is imperative that a programmer have a comprehensive understanding of the particular procedure to be put on the machine. He cannot do the best job by merely translating the present semi-manual system. Rather, he must understand the problem thoroughly in order to utilize fully the capabilities of the machine he expects to use.

Simplified computer and its instruction list

The outline prepared by the analyst —perhaps in the form of a flow-chart— must be placed in machine language. To illustrate how the program or code may be drawn up, a simplified computer will be assumed and a short problem worked out. The computer will have the following features:

a. Single address[a].

b. Memory or storage capacity of 4,000 words, each of fixed length and containing ten digits and sign[a].

c. An accumulating or "A" register of ten digits and sign in which arithmetic operations are done[a].

d. A ten-digit register used as an extension of the A register and known as the R register. During shift operations, A and R act as a unit.

e. A register to control the computer during execution of commands, (not explained in this example).

The operations or instructions assumed fall into these categories:

1. Arithmetic operations: These include the usual fundamental operations to carry out the calculations.

2. Store results: Intermediate results to be reused or printed out are removed from the registers and placed in the storage or memory.

3. Shifting operations: To examine certain digits in a register, it may be necessary to move the number to the right or left in the register, as is usual with a desk calculator.

4. Branching operations: These commands enable the computer to choose one of two sections of the program. For example, the computer can choose the correct portion of the program to answer a question "yes" or "no", depending on whether a critical number is zero or not zero. This feature will be illustrated.

5. Change control: The computer is assumed to take its instructions from sequential addresses in storage. The program may be selected from a new point by including the change of control command.

6. Input-output: These commands load program and data into the computer and print out the results.

The specific instructions to be used in the problem are shown in Table I.

To illustrate the preparation of a specific program, a code is presented for a simple bank-check reconciliation problem. The formulation or analysis in the form of a general outline is shown in Table II.

Starting from this outline, the programmer first considers the input to the system—that is, what data are necessary to make the check reconciliation. They are:

1. The check number and the amount of each check returned.

2. The number and amount of each check written since the last reconciliation, as recorded on the stubs.

3. The balance as given on the bank statement.

4. The balance as given on the last check stub.

5. The check number and amount of "holdover" checks. Since the checks returned very seldom include all the checks written, a means must be found to "hold over" until the next reconciliation those checks which have been written but not returned.

After deciding what data are to be inserted into the computer, the programmer must decide the form and order of insertion of each piece of data. In this example, the programmer might first decide that each list of checks is to be put in numerical sequence by check number before loading into the computer. This would simplify the coding considerably. He might then decide that the amount of the check will be stored in the last seven digits of a word and the check number stored as the first three digits of the same word.

Next, memory space must be assigned for the program and each type of input. To do this, the programmer must know the maximum amount of each type of input, so that during loading none will overlap. In this example, the input words containing the holdover checks may be stored starting at memory location 0000. Immediately following the holdover checks, the words containing the check numbers and amounts of those checks written since the previous reconciliation may be stored. Thus, holdover checks and written checks lose their uniqueness by being combined into one group. During the reconciliation, any check of this group may become a holdover for the next reconciliation if it does not match with a returned check.

The list of returned checks may be stored, starting at memory location 1000. The statement balance and the stub balance may be stored in locations 0998 and 0999 respectively, thus allowing storage in this program for 998 checks in the holdover and written group. The program itself may be stored starting at memory location 3000.

The next step in programming is drawing the detailed flow chart. The chart shown in Figure 1 has been considerably simplified so that it handles only a few of the possible error situations. It could, of course, be expanded to include whatever checking feature are desired. In the flow chart, the words "written checks"

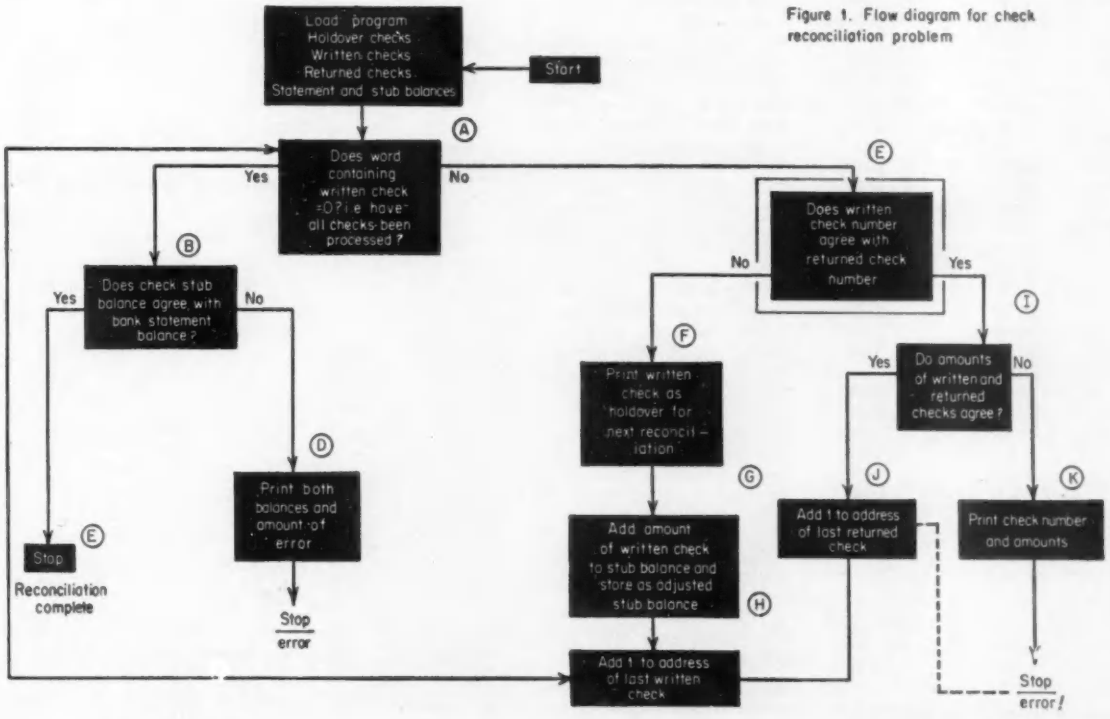


Figure 1. Flow diagram for check reconciliation problem

TABLE III

PROGRAM FOR BANK CHECK RECONCILIATION

The coding for each box of the flow diagram is indicated by brackets and a letter which corresponds to the letter on each box. Though certain instructions of the diagram do not properly fall within any block of the diagram, they are necessary for manipulation of the data. Instructions for loading the program or data have not been included.

Instruction location		Order	Operand address	Explanation
(A)	3000	CAD	(0000)	Bring written check to *A* register
	3001	CNZ	3003	Test for end of written check file
	3002	CU	3038	Change control to 3033 at end of file
	3003	ST	3100	Store written check in working storage
	3004	SR	0007	Shift amount into *R* register
	3005	STC	3101	Store written check number into working storage
	3006	SL	0007	Shift amount from *R* to *A*
	3007	ST	3102	Store written check amount into working storage
(E)	3008	CAD	(1000)	Bring word containing check returned to *A*
	3009	ST	3103	Store returned check into working storage
	3010	SR	0007	Shift amount into *R*
	3011	SU	3101	Subtract number of written check
	3012	CNZ	3020	Compare check numbers
(I)	3013	SL	0007	Shift returned check amount from *R* to *A*
	3014	SU	3102	Subtract amount of written check
	3015	CNZ	3030	Compare amounts
(J)	3016	CAD	3008	Bring command containing address to *A*
	3017	AD	3029	Add "1" to check returned address
	3018	ST	3008	Store command with modified address
	3019	CU	3025	
(F)	3020	CAD	3100	Bring to *A* the written check from working storage
	3021	PTW	0010	Print holdover
(G)	3022	CAD	3102	Bring written check amount to *A*
	3023	AD	0999	Add stub balance
	3024	ST	0999	Store adjusted stub balance
(H)	3025	CAD	3000	Bring instruction to *A* register
	3026	AD	3029	Add "1" to address of written check
	3027	ST	3000	Store modified instruction
	3028	CU	3000	Return to process next check
	3029	+0000 00	0001	Constant for modifying
(K)	3030	CAD	3103	Bring word containing returned check to *A* register
	3031	PTW	0003	Print check number
	3032	PTW	0007	Print returned check amount
	3033	CAD	3100	Bring word containing written check to *A*
	3034	SL	0003	Shift check number out of *A* register
	3035	PTW	0007	Print written check amount
	3036	STOP	0001	Discrepancy between stub and check amounts
	3037	CU	3016	Continue program after stop if desired
(B)	3038	CAD	0998	Bring statement balance to *A*
	3039	SU	0999	Subtract adjusted stub balance
	3040	CNZ	3042	Compare adjusted stub balance and bank balance
(C)	3041	STOP	0000	Stop on correct reconciliation
(D)	3042	CAD	0998	
	3043	PTW	0010	Print statement balance
	3044	CAD	0999	
	3045	PTW	0010	Print adjusted stub balance
	3046	STOP	0002	Stop on error between adjusted stub balance and bank balance

The addresses in instructions 3000 and 3008 (enclosed in parentheses) are changed as each check is examined. Thus up to 998 checks may be reconciled using this same instruction list. The address-modifying portions of the program are in Sections J and H.

mean the group composed of both holdover and written checks.

Since the number of written and returned checks may vary for each reconciliation, a word containing zeros is loaded at the end of each input. Before processing each word containing the written check, it is checked for zero. When the word containing zero is reached, the comparison part of the reconciliation has been completed–all incoming check numbers have been matched against assigned and available numbers.

After the flow diagram has been completed, the coding of the problem may begin. The instructions listed must be those which will accomplish the operations shown in each box in the flow chart. For example, Box E requires that the number of each check returned must be compared with the number of a holdover or written check number. The instructions to accomplish this are as follows:

Function	Instruction
Bring word containing check returned to A register	CAD (1000)
Shift amount into R register	SR 0007
Subtract number of written check	SU 3101
Check for 0 difference	CNZ 3020

If it is zero, the check number agrees with the returned check number. Then the program proceeds to Box I. If the difference is not zero, the written check must be retained as a holdover for the next reconciliation (Box F). The full program is shown in Table III. Thus, the reconciliation of many checks may be accomplished by this one program, which can be used over and over.

Code correcting or debugging

The example shown is intentionally very simple. Many programs will have many different decision parts or loops and will have much larger arithmetic sections. General experience has indicated that most codes, even simple ones, may have errors when first written. Code correcting or debugging is almost invariably required before an error-free program is obtained. One of the procedures frequently used is to work out manually the results for a typical set of data; then, during machine calculation, stop the program occasionally or print out results and match them against precalculated checks. In some cases, the programmer may do a step-by-step check of parts of his program, observing the results as he goes. Most machine users are using programs which themselves test new programs. They provide print-

out of results and program information at certain key instructions—in other words, they monitor the program. Other types of programs are dubbed "post mortems", since they are used when the program is allegedly dead. Once an error is made, the post mortem prints out the pertinent information to aid in finding out why. To summarize, direct comparison with manual results coupled with either stepping through a difficult or erroneous section, plus programs which provide information as to where the program went wrong, enable the coder to detect the errors and correct them.

Combined operation

Most computers not only have the basic operations which were postulated in Table I, but many other special commands and devices. For example, the changes of addresses and the tallying of such changes are both simplified by using the "B register" or the "index register". This enables the coder to add a number which is stored in a specified register to the address portion of the tagged instruction without altering the instruction itself. Some machines have built-in instructions which permit floating point operations without subprograms. Others have special instructions to compute square roots or quantities, such as sums of products. Where an operation is to be used frequently, special computers can be built. However, what is accomplished by these special devices can be accomplished with a general-purpose machine by the basic instructions if some loss in time can be tolerated. At the present state of the art, most machines represent a compromise between the basic instruction list and the highly specialized possibilities. In almost all cases, some special-purpose instructions are incorporated in a good general-purpose machine.

Subroutines

Where an operation is to be used with fair frequency, and a specific instruction is not available, a subroutine can usually be prepared. This is usually a short program which has been polished so that it is very near minimum-time for the particular machine. For example, the entire program of the example in Table III might be a subroutine or subprogram in a larger program for handling an account, including deductions, deposits, etc. An efficient integrated system of subroutines will extend the vocabulary of the machine to almost any degree desired. Having once written a suitable subprogram, the programmer may later simply specify the formula. For example, he may call for a subroutine to compute $a + b e^x$ for certain ranges of each constant. Another program may carry out various matrix operations, such as multiplication, addition, vector-matrix multiplication, inversion, and the like, so that the programmer needs only to stipulate the order of the matrix and the accuracy of his results. After such a library is available, coding becomes much simpler. However, a great deal of thought and ingenuity must go into the library itself to make it useful and close to the efficiency of the directly written codes.

Once the subprograms are available, it is possible to so code the machine that it, itself, will take over most of the work in compiling a new code. These techniques are becoming more important because of the shortage of programming talent[4].

To summarize, the problem must first be explicitly and clearly formulated, the steps in the formulation placed into a logical sequence in outline or flow-chart form; then each step of the flow chart must be translated into the machine language or code. Once the formulation is complete, the coder's work can be minimized by use of subroutines, automatic programming, and compiling. Effectively, the work of the analyst can be then carried directly to the machine in terms of general statements, rather than in terms of step-by-step code.

Regardless of any coding simplifications, the job of formulation and analysis still remains. There is great need for competent analysts and programmers with experience in electronic computation.

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WALLACE KLAMMER

Mr. Klammer, formerly in Lockheed Aircraft's Computer Div., joined ElectroData in 1954. As supervisor of industrial applications, he is responsible for the development of uses for ElectroData equipment in manufacturing, processing, and allied fields. Klammer was the one who programmed ElectroData's Datatron computer to predict the outcome of sports events. He holds a degree in mathematics from the University of Minnesota.



SIBYL ROCK

Sibyl Rock was a research associate with Consolidated Engineering Corp. when that company first began computer studies. She joined ElectroData Corp. as a sales engineer at its founding in 1953, and today is assistant to the director of marketing for the ElectroData Div. of Burroughs Corp. Much of her work consists of explaining digital computers to people in management, a job that has seen her cover 30,000 miles in a single year. She has a BA degree in mathematics from UCLA.

Relay "Memory" Speeds Conveyor Transfer

Automotive assembly line conveyor transfer system uses latching relays to remember orders, tracks car bodies to prevent collisions, and clears memory when transfers are completed.

J. W. OPEL, General Electric Co.

In automotive assembly plants, the output of one or more conveyors must often be programmed to a number of subsequent conveyors as, for example, after the semi-finished bodies have been given the final coat of paint. The assembly system at Ford Motor Co.'s Mahwah, N. J., plant requires at this point that the various passenger car and station wagon bodies be separated by "type" and placed on slow-moving "storage" conveyors. The cars are brought into the transfer system via the weatherstrip conveyor (*B*) or the power accessories conveyor (*A*) (see Figure 2), after final paint inspection.

As a unit approaches the unloading end of conveyors *A* and *B*, an operator will select by pushbutton the correct storage conveyor for the body. This is the operator's only duty during normal automatic operation. He can select single- or double-unit transfers for adjacent body models.

The controls for the system of Figure 2 would be quite simple if only one unit was to be transferred. But the system must transfer up to five units simultaneously to maintain optimum speed on conveyors *A* and *B*, and must also prevent possible collisions between units during transfers.

The transfer system remembers the operator's selections by means of sealin relays, mechanically-held relays, and timers. Because the system uses adjustable speed conveyors, unit position cannot be indicated by timers, which provide only the double-selection pushbutton function. Position indication is made by limit switches, connected so that the limit switch "trip" will look ahead to the next area to check if the area is clear. When the unit leaves an area, it releases a limit switch, thereby clearing the area for entry by a subsequent unit.

When the system is completely analyzed by these areas, the position of every load is known and the combination of all areas provides a flow of units into the storage conveyor area. Although normal flow calls for all selections to be memorized and the transfer completed automatically, any or all portions of the system may be made to operate manually. On the operator's desk is a complete set of manual pushbuttons with which he can perform the function of any limit switch manually.

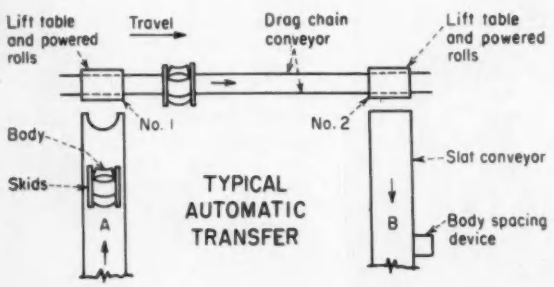
The main control panel for this system of constant and adjustable speed drives is a General Electric IC7092 Motor Control Center. This center provides all of the power distribution for the system through combination starters and relay panels. The starters are energized in the desired sequence by a panel of approximately 60 control relays. These relays provide both the automatic memory and manual sequence functions for the system.

Possible transfer sequences

A body approaching the end of the weatherstrip conveyor (*B*) can follow any of six transfer sequences, which are controlled by pushbuttons in the control desk furnished with this five-station passenger-body transfer conveyor. One of the sequences applies to the turntable and manual transfer car, the other five to this conveyor (see Figure 2).

Sequence A. Pushbutton energizes the selective automatic circuit to transfer the load to storage conveyor *J*. The load travels across the power-turntable onto lift-table 5 and stops in that position until transfer conveyor (*E*) reverses (when the previous load has been discharged). Lift-table 5 then lowers and deposits load on the transfer conveyor. The load travels along the transfer conveyor onto table 6, which rises and discharges it into storage conveyor *J*.

Sequence B. A pushbutton selection transfers a load to storage conveyor *H*. The load travels across the power-turntable onto transfer table 5,



A simple transfer is shown here for illustration only. A partially completed body mounted on skids is traveling on conveyor A. As the body approaches the end of conveyor A, the skid trips a limit switch which causes lift-table 1 to rise. When body is properly loaded on table 1 the table lowers and the body is deposited on the transfer (chain conveyor). The body then progresses to the table 2. Another limit switch raises table 2 and starts powered rolls 2 to deposit the body on conveyor B. When body had cleared table 2 onto B, the table lowers automatically to receive the next load. Body travels through body spacing device on conveyor B to obtain proper spacing for further assembly work stations. Electrical interlocking assures that tables are in proper positions at all times. The control circuit also always prevents any possibility of collisions regardless of the speed setting of the adjustable speed conveyors.

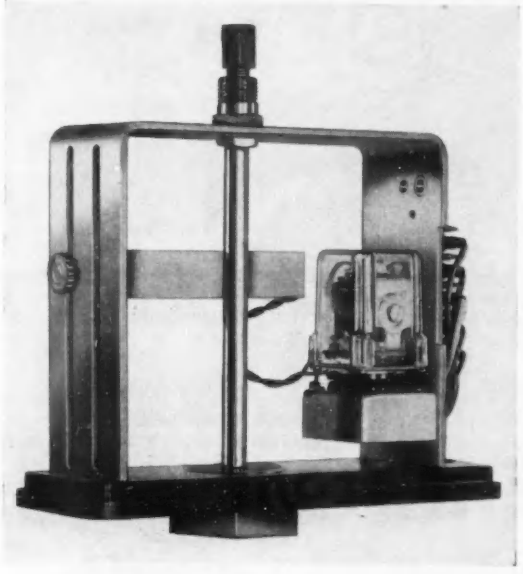
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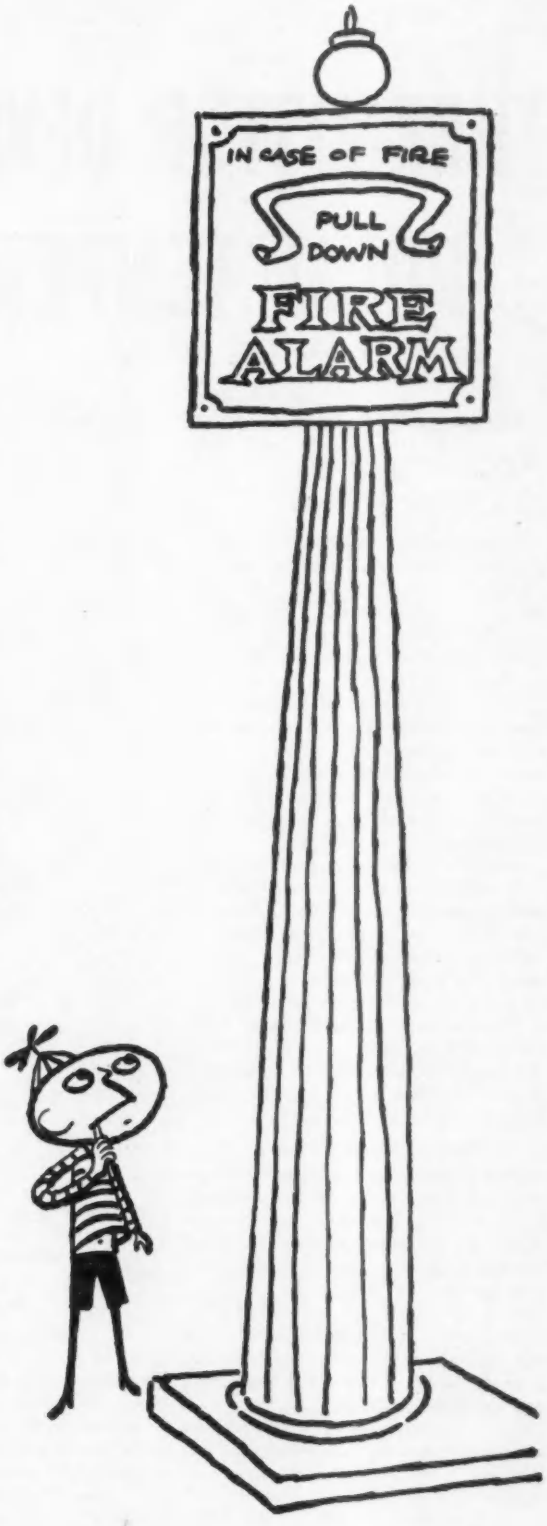
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COMPLETE PROCESS INSTRUMENTATION

LA 1153

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But possibly the biggest news in the design is the way the Unit Controllers can be assembled with a common power supply, like building blocks, to provide you with a central system serving up to 100 control points.

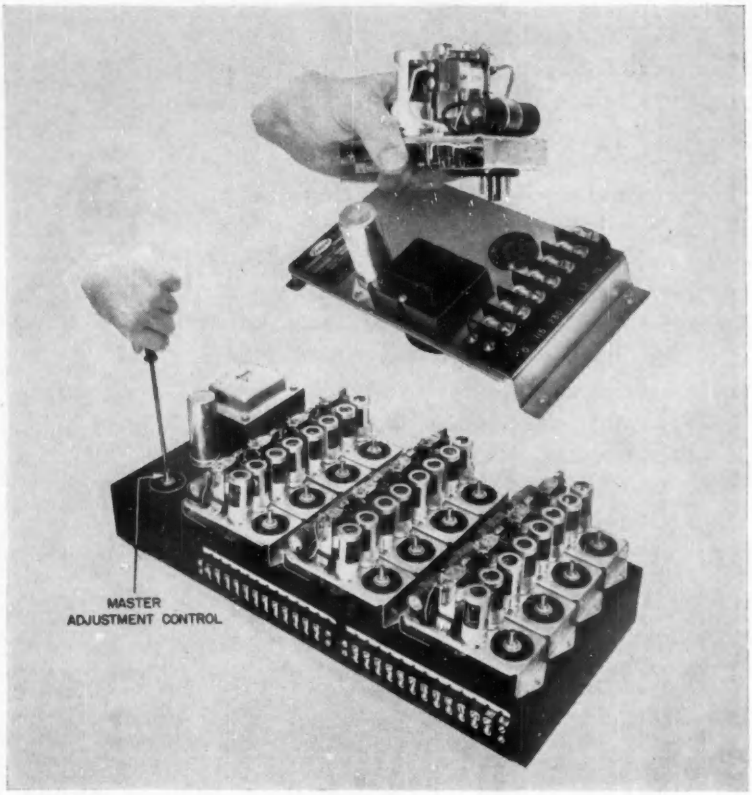
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which lowers and deposits load on the transfer conveyor. The load travels along the transfer conveyor to table 4, which then rises and discharges load onto storage conveyor *H*.

Sequence C. Pushbutton energizes the selective automatic circuit to transfer the load to body storage conveyor *I*. Load travels across power-turntable and roll bed and lift-table 5 (in "up" position) directly onto storage conveyor *I*.

Sequence D. Pushbutton energizes the selective automatic circuit to transfer the load to body storage conveyor G. Load travels across power-turntable onto lift-table 5, which lowers and deposits load onto the transfer conveyor. The load travels along the transfer conveyor until it approaches lift-table 3 and trips a safety limit switch. If table 3 is in the "up" position, the transfer stops until the table is lowered. If table 3 is down, the transfer conveyor continues to run. The load on the transfer conveyor continues until it is on table 3, which then rises and discharges it onto storage conveyor G.

Sequence E. Button energizes the selective circuit to transfer the load to conveyor *F*. This sequence is the same as *D* except that the load travels to lift-table 2.

The system is required to deliver the output of the power accessories conveyor (A), which may be programmed to storage conveyor *F* or *G*. The sequence for each of these is similar to the sequences for *B* and *C*.

Typical circuit operation

A sample circuit is shown in Figure 1 for a selection from conveyor *B* to storage conveyor *J*. Refer to Figures 1 and 3 to follow the description of circuit operation.

If the prior-selected final load has passed table 5, the first load selection of PB-2B will cause the pick-up of CRB1 if a load is on LS1-B. When the first load enters table 5 by tripping LS2-7, the transfer relay CRB3 is picked up to establish a pick-up circuit for CRB2. When a second selection of PB-2B is made with the second load over LS1B, relay CRB2 will be picked up. When the first load of PB-2B trips LSA-6, the pick-up of CRB6 unlatches CRB1. This completes the first load cycle to *J* conveyor storage. Relay CRB3 is dropped out by the pick-up of CRS2 for the second load entering table 5. This completes the double selection by PB-2B. It can be repeated.

The single selection program is as follows:

If all prior-selected loads have cleared table 5, i.e., there is prior-selection cancellation or dropout of relays CRH1, CRF1, CRF2, etc., CRB5 is picked up. Relay CRB5 will start the transfer-conveyor motor forward. CRB1, picking up, starts loads from *B* to the turntable. LS2-B trips and starts the turntable rolls and

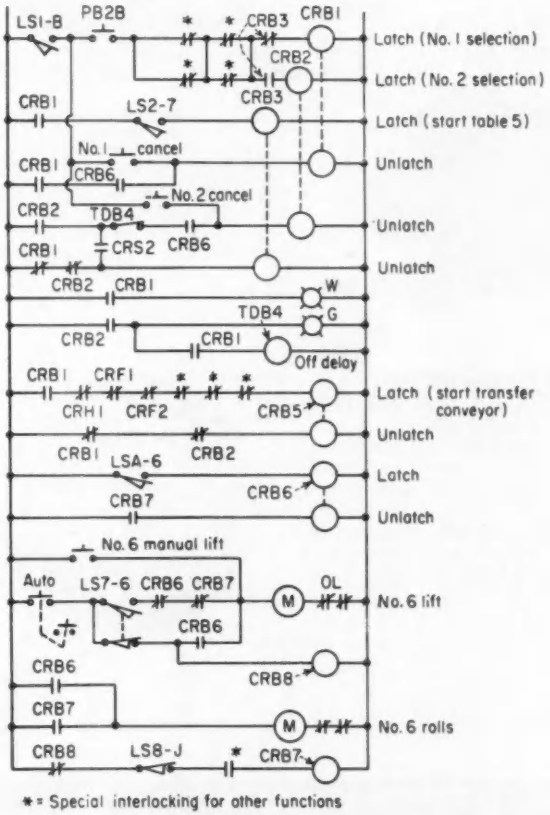


FIG. 1. Sample circuit showing relay connections for transfer from B to J.

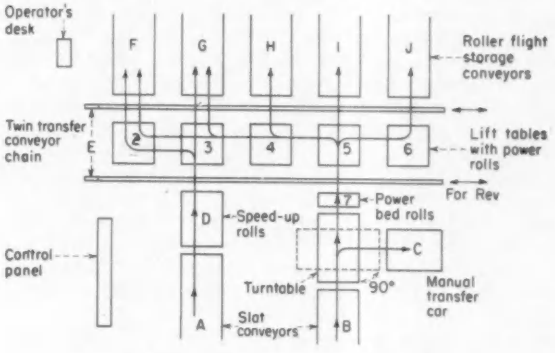


FIG. 2. Automatic system for transferring car bodies from two delivery conveyors to five storage conveyors.

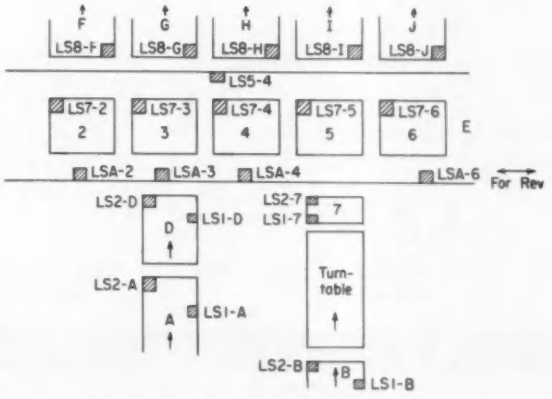


FIG. 3. Simplified limit switch diagram for system of Figure 1.

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starts rolls 7. When the load trips LS2-7, and picks up CRB3, lift-table 5 starts to raise and starts roll 5. When table 5 is raised, the load release of LS2-7 stops rolls 7 and 5 (not shown), and table 5 lowers to the *E* chain for load transfer to table 6.

When the load trips LSA-6, as indicated by the pick-up of CRB-6, and raises table 6 to start roll 6, it also cancels the selection PB-2B, as indicated by the dropout of CRB-1. Trip and release of LS8-J lowers table 6.

The selection of a load from conveyors A to G may be made during this cycle. However, a selection of a load from *A* to conveyor *F* may progress only to table 3. The load on table 3 will then be held until the transfer conveyor chain *E* is reversed to enable the load lowering from table 3 to be transferred to table 2 and into the desired storage conveyor *F*.

Simultaneous transfers

The operator may call for a transfer from *A* to *G* at the same time as from *B* to *H*, and may follow with a transfer from *B* to *F*.

In transferring from A to G, the load from conveyor A will trip limit switch LS1-A, stopping conveyor A if powered rolls *D* contain a load. If powered rolls *D* are empty, the load will progress to LS2-A. Tripping LS2-A will energize rolls D. The load then progresses to LS1-D, where it will stop if a previous selection has not been cleared from conveyor *B* to *F* or G. With a clear road ahead, the load will progress to LS2-D. Tripping LS2-D will cause table 3 to lift and start powered rolls 3. Load will progress across table 3 and the trip of LS8-G will start conveyor *G*. The release of LS8-G will allow table 3 to return to its normal down position and the powered rolls on table 3 will stop. This will complete this sequence. During this sequence from *A* to *G*, any load from conveyor *B* going to *F* or G will be stopped when the load reaches LS5-4.

The transfer from *B* to *H* followed by *B* to *F* is as follows:

The first load tripping LS1-B will be selected to go to storage conveyor *H*, then to LS2-B, where it will energize the powered rolls on the turntable. The load will now progress to LS1-7. Tripping LS1-7 starts the powered rolls on table 7. Tripping LS2-7 will cause table 5 to rise and start powered rolls on 5. When the end of this skid releases LS1-7, the turntable powered rolls will stop. When the body is correctly loaded on table 5, as indicated by the release of LS2-7, table 5 rolls will stop and the table will be lowered. This will cause the body to be lowered to chain conveyor *E*, which then transfers load in the direction of conveyor *H*.

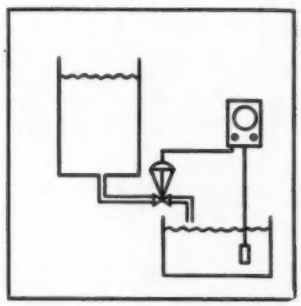
In the meantime, a second load tripping LS1-B will be selected to go to conveyor *F*. It will progress to table 5 the same as load 1, but it cannot be lowered from table 5 until the first selection to conveyor *H* has been cleared. The first selection now has progressed to LS7-4. Tripping LS7-4 causes table 4 to rise and powered rolls on table 4 to direct the load to conveyor *H*. Tripping LS8-H starts conveyor *H*. The release of LS8-*H* will lower table 4 and table 5 containing the second load. The second load then progresses on chain conveyor *E* to table 2 unless stopped at LS5-4 by a second transfer from *A* to *G*. If the way is clear, the load will progress to LS7-2. Tripping will cause lift-table 2 to rise and rolls 2 to start. Load is deposited onto conveyor *F* and the release of LS8-F causes table 2 to lower and cancel the selection.

By this combination of "trip" and "release" of limit switches to indicate clear or congested areas ahead and behind a given load, any program selection may be made collision-proof by means of protective relays.

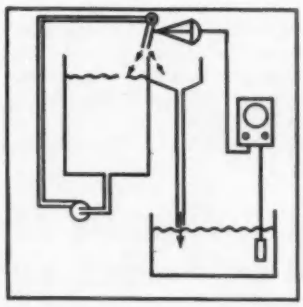
Maximum load for this system is the set of circumstances in which a load scheduled from *A* to *F* is on table 2, and a load from *A* to *G* is on table 3. At the same time, a load scheduled from *B* to *H* may be on table 4 and a load from *B* to *I* on table 5. Also, a load from *B* may be required to go to *C* by rotating the turntable 90 deg. Here five loads are in transit safely.

Systems similar to the one in Mahwah are in operation at Ford assembly plants in San Jose, Calif.; St. Louis, Mo.; and (soon) Kansas City. Each plant contains approximately four of these complex systems and 30 to 40 simple transfers.

Plugging Slurry Valve?

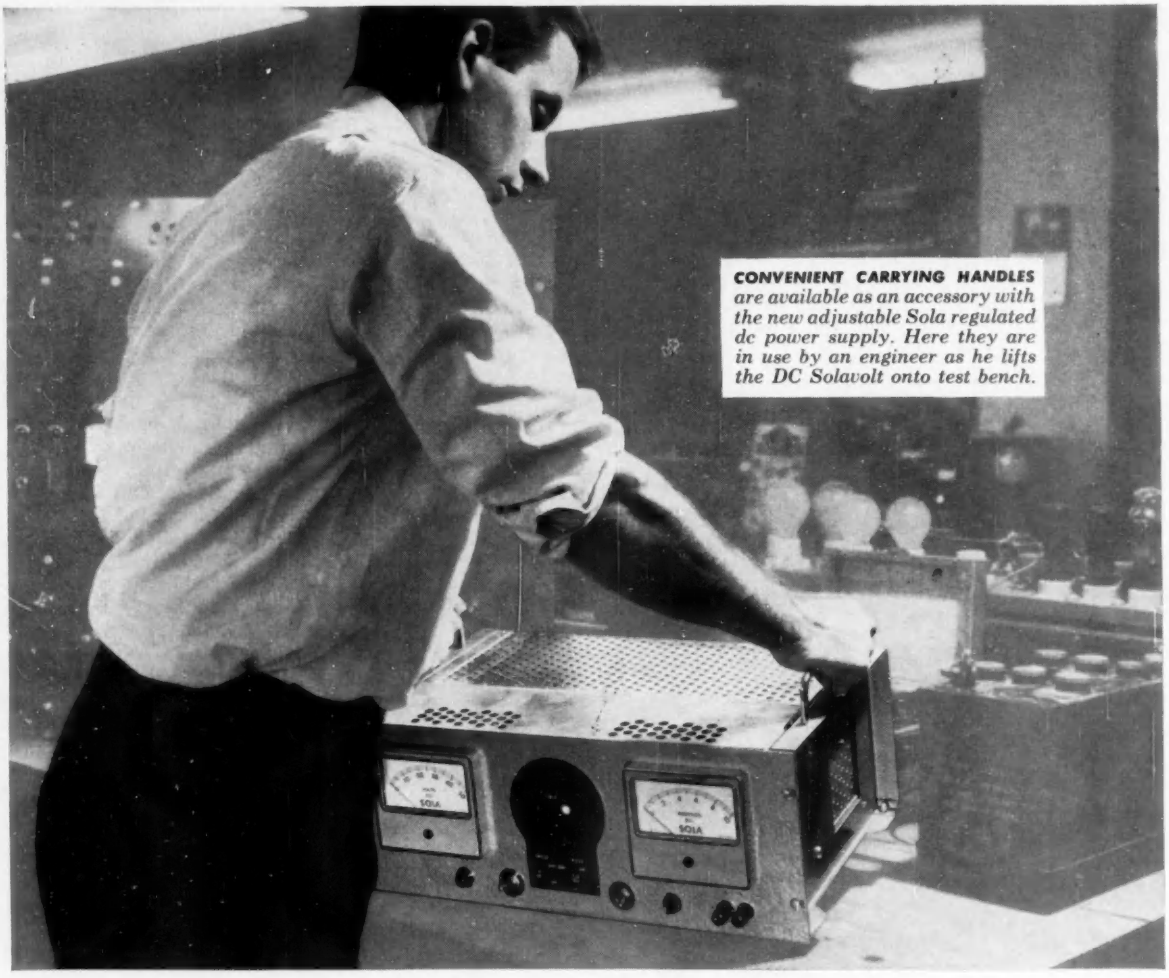


Plugged valves are one of the problems commonly encountered when attempting to control the flow of liquids containing suspended solids. If the valve is in a control loop and begins to plug, the controller pen will eventually depart from the index setting. The resultant controller action will cause the valve to open wider and wider in an attempt to restore equilibrium. When finally the clot breaks free, the excessive rush through the valve may cause the pen to overshoot in the opposite direction.



Try This . . .

One successful solution to this problem, which has found wide use on paper-stock slurries but is not yet common knowledge elsewhere, is offered by the flow splitter. The tank contents are continuously recirculated by means of a pump. Part of the recirculated stream may be split by a diverting vane as determined by the position of a swinging nozzle. The nozzle is positioned by an actuating mechanism according to the dictates of the controller.



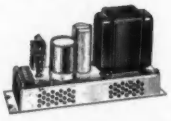
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Scanning Improves Headlight Dimmer

This dimmer for automobile headlights scans the road ahead for bright points of light. Thus, it discriminates against the general ambient light level, and can "see" approaching headlights over 2,000 ft away even at early dusk.

J. RABINOW, Rabinow Engineering Co.

At first thought, design of an automatic headlight dimmer for automobiles would seem rather simple. But the Patent Office files are full of ideas, and there still is no completely satisfactory solution to this problem. The difficulty is that a headlight dimmer must perform several rather difficult functions.

A headlight dimmer must "see" oncoming headlights, even if these are in the downward position, at least 1,000 and, preferably, 2,000 ft away. It must not respond to light from its own headlights reflected by various objects on the road. It should not see signs, porch lights, etc., which are often present along the road. It should not respond to ambient light, such as light from the sky at dusk and dawn, and moonlight. If the dimmer has gone down on another car's bright lights, it should go "up" when the other car dims its lights.

Theoretically, the dimmer should also become more sensitive as the ambient light drops, in order to compensate for the increasing glare factor. It should "dim" on the tail-lights of a car ahead when that car is 2-300 ft away so as not to bother the driver ahead by reflections in his rear-view mirror. In short, a dimmer should have nearly human intelligence.

Most of these reasons make impractical the relatively simple dimmer that responds to the total light coming from a large solid angle ahead of the car. The human eye sees oncoming lights, not by integrating the total illumination taken from the frontal area, but by detecting, by means of its sensitive mosaic, one or two bright sources against the background. In order to do this in a dimmer, two approaches are possible: One is to use a simultaneous system, such as in the eye. This would require either a photocell with many small sensitive spots or a mosaic of cells; the other is to revert to one of many possible scanning systems. This was done in the dimmer described in this article. The dimmer shown in Figure 1 employs a photomultiplier ahead of which is a small Nipkow disc scanner. This system is shown schematically in Figure 2.

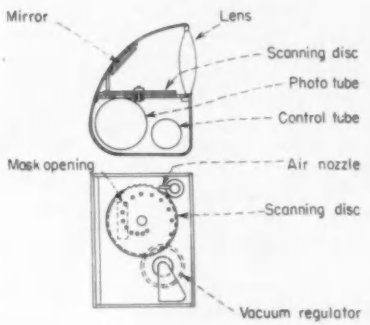




FIG. 1. Sensitive headlight dimmer uses Nipkow scanning disc propelled by air.

The scanning dimmer

The Nipkow scanner is a disc provided with a spirally arranged set of holes, overlapping each other radially by about 50 percent, so that as the disc spins, every elemental area of the image rectangle is covered during each revolution. In this way, when a particular hole reaches the elemental area on which the headlight of an oncoming car is imaged, all of the light gathered by the lens from that headlight goes through this hole and impinges on the sensitive areas of a photocell directly behind it. This cell puts out a "spike" of electric current, which is amplified, detected by a peak detector, integrated over a short period of time, and made to operate a relay which dims the headlights of the car.

It will be seen that if a peak detector is used, the average light has no effect on the output—only the largest spikes produce an effect. The system is normally ac-coupled; that is, the dc level from the phototube is not passed to the amplifier and only the difference between a bright spot and background produces an ouptut. Thus, the darker the background, or the darker the night, the more sensitive will be the dimmer and the more nearly it approaches the action of the human eye.

If the dimmer were made sensitive enough to see tail-lights of most cars at 300 ft, it would see headlights much too early and too far away. By using a red filter ahead of the phototube to favor red lights in general, or by using a red-sensitive phototube, the gain can be kept high enough under most conditions, particularly in the east, so that tail-lights can be seen (or at least kept in view after the dimmer has operated) quite well up to about 250 ft.

Other features

One can do many tricks with a headlight dimmer. For instance, since the headlights of automobiles are almost

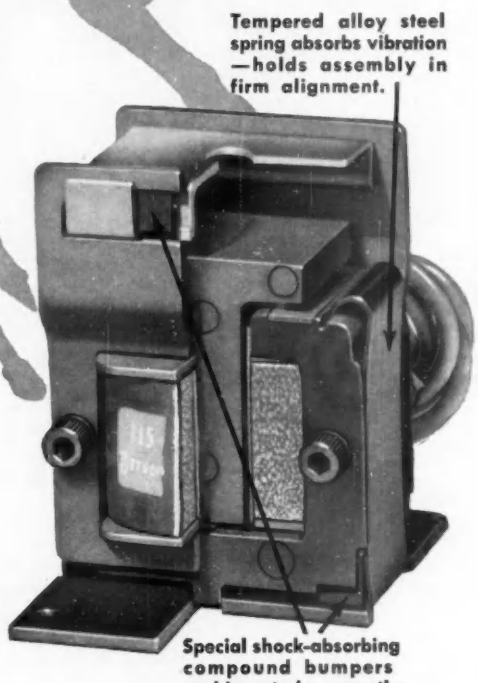
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universally operated by dc, and the lights along the sides of the road are almost universally supplied by ac in the U.S., a filter could be added to the system to detect the presence of ac light so that it will dim only on lights energized by dc. In practice, this has certain complications when both types of light are present, and it is not justifiable, particularly because most of the side lights are of lower intensity than headlights and do not cause much trouble. Occasionally the dimmer will see a bright house light or a street light directly in its path, particularly on a hilly and curvy road, and will respond to such lights. This is of no consequence as the road is usually illuminated by such lights and one hardly notices this action. In the city, the ever-present lights cause the dimmer to stay down, which is just the way it should be.

Another interesting problem was to prevent the dimmer from acting on light from its own headlights reflected by a beaded sign or some other mirror-like device. If there were a true mirror in the front of the car, the dimmer would apparently have no way of knowing whether the light it sees is from its own car or from another. The approach used to lick this is as follows: Assume that a light is seen and the device does not know what light that is. It therefore dims its own lights. If nothing happens immediately after this (within a tenth of a second) the dimmer can safely assume that it sees lights belonging to another car. It is very unlikely that the other car would also dim its lights within a tenth of a second. This can happen, of course, but only very, very rarely and is of little consequence. If, however, the dimmer dims the lights and notices within a tenth of a second that the input to it has dropped by a factor of 10 to 1, it can conclude that the lights it sees belong to the car itself. It can then immediately lift the lights by lowering its own gain.

In practice, then, when a beaded sign produces a very bright spot in the dimmer, the lights flick down, the gain is immediately reduced, the lights come up and an RC circuit gradually returns the gain to normal in about 2-3 sec. By this time the car has passed the sign and the driver has hardly noticed it. If he stops directly in front of the sign, the lights will flicker once every 2 sec, but only for a short flick. This is not objectionable. Without this circuit, the lights would flicker steadily at about three to four times per second, which is quite annoying.

The gain is not killed completely because a car may come out of a side street during the period of low gain and the dimmer should operate.

A "hold" circuit must be provided for a dimmer so that if it dims on another car it must not "lose" the other car when the lights it sees also go "down". This is done simply by providing a margin of gain in the dimmer and operating it normally at about $\frac{1}{10}$th of its high gain. When it sees headlights and dims, the gain is made to jump by the factor of 10 so that if the other car should now dim its lights, they will still be seen. This means that the dimmer normally is operating at less than maximum gain, and therefore at greater stability. Unfortunately, it also means that the dimmer must be built with very great gain so that even when the gain is reduced by a factor of 10, there is still more than enough to see other headlights.

Another point of general interest is that a dimmer which is insensitive to general light can be mounted almost anywhere on the car, including a location in the proximity of one of the headlights. If scanning is not used, the general "wash" of light from the headlight beams causes a great deal of trouble. However, any dimmer should normally be mounted high and to the left, so as to see over hills as soon as possible. If it is mounted at the height of the headlight, or lower, the driver of the other car might see the undimmed lights before the dimmer sees his lights. If the dimmer were mounted on the roof of the car, preferably to the left side so as to see around cars immediately ahead, it would be most "polite", and dim before the driver of the oncoming car could see the headlights.

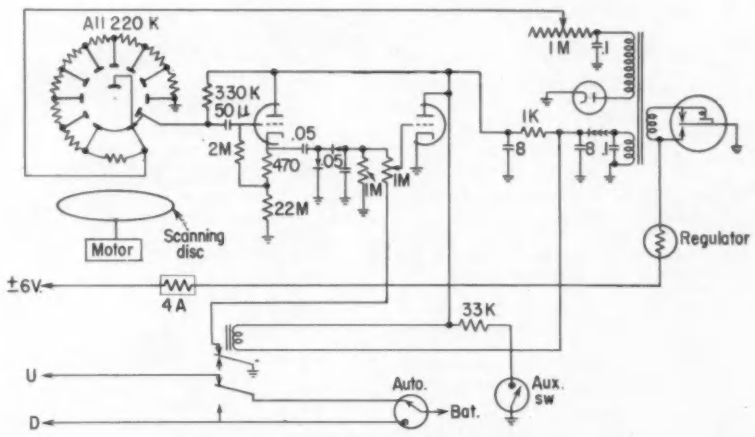


FIG. 2. For the interested home hobbyist, here's the entire circuit. Its functions are described in the text.

Nipkow disc drive

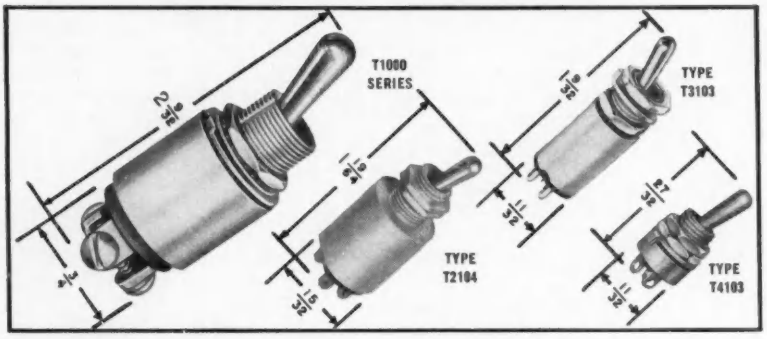
In the dimmer of Figure 1, the Nipkow disc is driven by air. A vacuum line is run from the engine to the dimmer housing so as to produce a partial vacuum in the housing, and air admitted to the housing through a small nozzle is made to impinge upon teeth cut into the edge of the disc. The disc is driven at high velocity and the arrangement results in a rather inexpensive and simple device. The complexity of running a vacuum line into the dimmer, however, and the difficulties with pressure regulation and air entering the dimmer do not make this approach worthwhile. Electric motors are cheap enough for this purpose and have been used in most models. The motors can be either dc or ac. Ac motors can be driven from the vibrator-transformer power supply used to power the dimmer.

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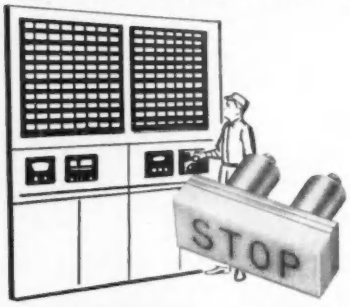
ENGINEERING NEWS #3

Say "WHEN" to Toggle SWITCH MINIATURIZATION



Few basic electrical components have been successfully miniaturized with such telling effect as the toggle switch. Hetherington has developed space- and weight-saving cylindrical types with ratings, dimensions, and performance tailored to the critical requirements of airborne and industrial electrical systems. And, thanks to Hetherington's positive cam-roller snap action, even the smallest types carry ratings far greater than their sizes would indicate.

Recent Hetherington developments such as the sub-miniature Type T4103 shown above approach the point where further miniaturization would seem to present more difficulties in mounting than in obtaining adequate switch performance. Although not quite ready for production, field tests of the T4103 have shown great promise for drastically cutting weight while assuring better performance in aviation's toughest jobs.



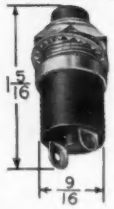
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Make Crowded Panels More Meaningful

Too often the significance of tiny conventional indicator lights is hard to determine at first glance—especially if many are used on one panel. With Hetherington Placard Lights, vital control information can be read directly in terms of symbols, digits, abbreviations, words, or entire phrases engraved on plastic lenses. Two miniature AN3140 lamps boldly illuminate the lettering, thus avoiding delay or errors of interpretation.

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standard switches for the most specialized requirements

Synchronize Alternators Automatically

This automatic synchronizer detects phase and frequency independently to determine the proper moment to connect a diesel-driven ac generator to an energized line. The circuit anticipates the instant of synchronism to compensate for relay closure times.

Before the output of a diesel-driven generator can be connected to a power distribution line, the generator's output must match the line both in frequency and in phase. An automatic synchronizer has been designed by Vickers Electric Div. of Vickers, Inc. that uses two independent circuits to detect phase and frequency matching. Reliability is high because neither circuit uses vacuum tubes or vibrating elements.

Phase detector circuit

The ultimate function of the phase detector circuit is energizing the circuit breaker which connects the generator output to the line so that the breaker closes at the instant of synchronism. The phase detector has no effect on the frequency or voltage of the generator; it only causes the main circuit breaker to energize at the proper time.

The phase detector circuit has two other functions besides phase detection:

Speed detection—The circuit breaker must not close when the frequency difference between the generator and the line is greater than $\frac{1}{4}$ cps.

Anticipation—The circuit breaker must be energized as much as 25 cycles before the instant of synchronism to compensate for the time required for the circuit breaker to close.

The phase detection action itself is limited by the requirement that the phase difference between the generator and the line be no more than 5 deg when the circuit breaker closes.

Figure 1 shows a simplified block diagram of the phase-detector circuit. In this circuit, single-phase voltages from the generator and the line are applied to similar networks. Each network includes a reactance, a demodulator transformer, and a resistance (magnetic amplifier L_1 is the reactance in the line leg). L_1 and L_2 are designed so that their cores will saturate at a fraction of the voltage applied. When the reactors saturate, their impedance drops to a low value and the remainder of the half-cycle of the applied voltage appears across the demodulator transformers and the resistors. Thus, as shown in Figure 2, the reactors absorb the first portion of each half-cycle of the input voltage.

The "trailer edge" of the voltage waveform in Figure 2 serves to indicate the point of synchronism. When the trailing edges of the waveforms from the line leg and the generator leg occur simultaneously, the demodulator circuit "fires" to energize control relay *B*. This relay applies power to a pilot relay, which energizes the main circuit breaker. Control relay *B* also is polarized, so that the negative output current of the demodulator, which occurs when the demodulator input pulses are 180 deg out of phase, does not cause it to close and initiate the synchronizing action.

Because the closing of the control relay, the pilot relay, and the main circuit breaker may take as long as 25 cycles, the instant of synchronism must be anticipated by this amount of time. The "anticipation signal" is taken from a dc tachometer generator geared to the synchro motor, whose speed of rotation is proportional to the line-to-generator frequency difference (rate of approach to syncronism); thus, the output voltage of the tachometer generator is also proportional to the rate of approach to synchronism. The anticipation signal is applied as a bias to magnetic amplifier

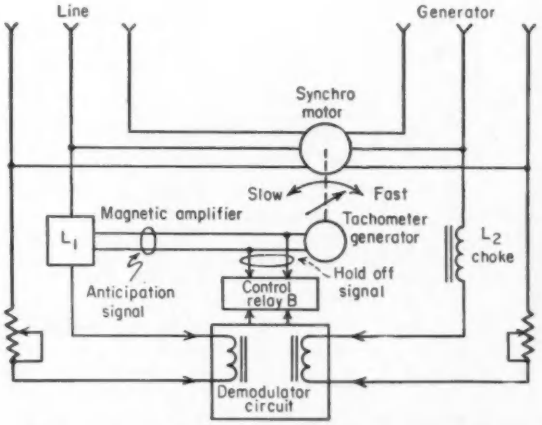


FIG. 1. Simplified phase detector circuit shows how anticipation and hold-off signals are derived from tachometer generator.

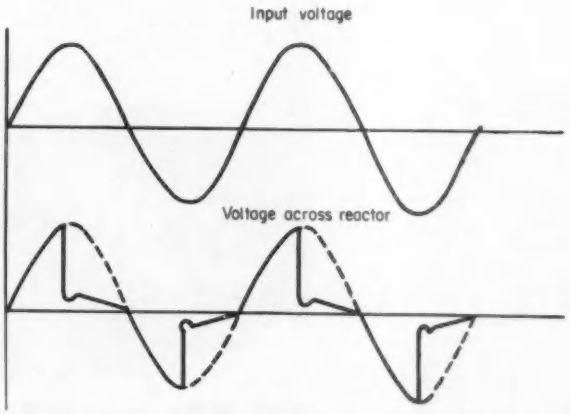
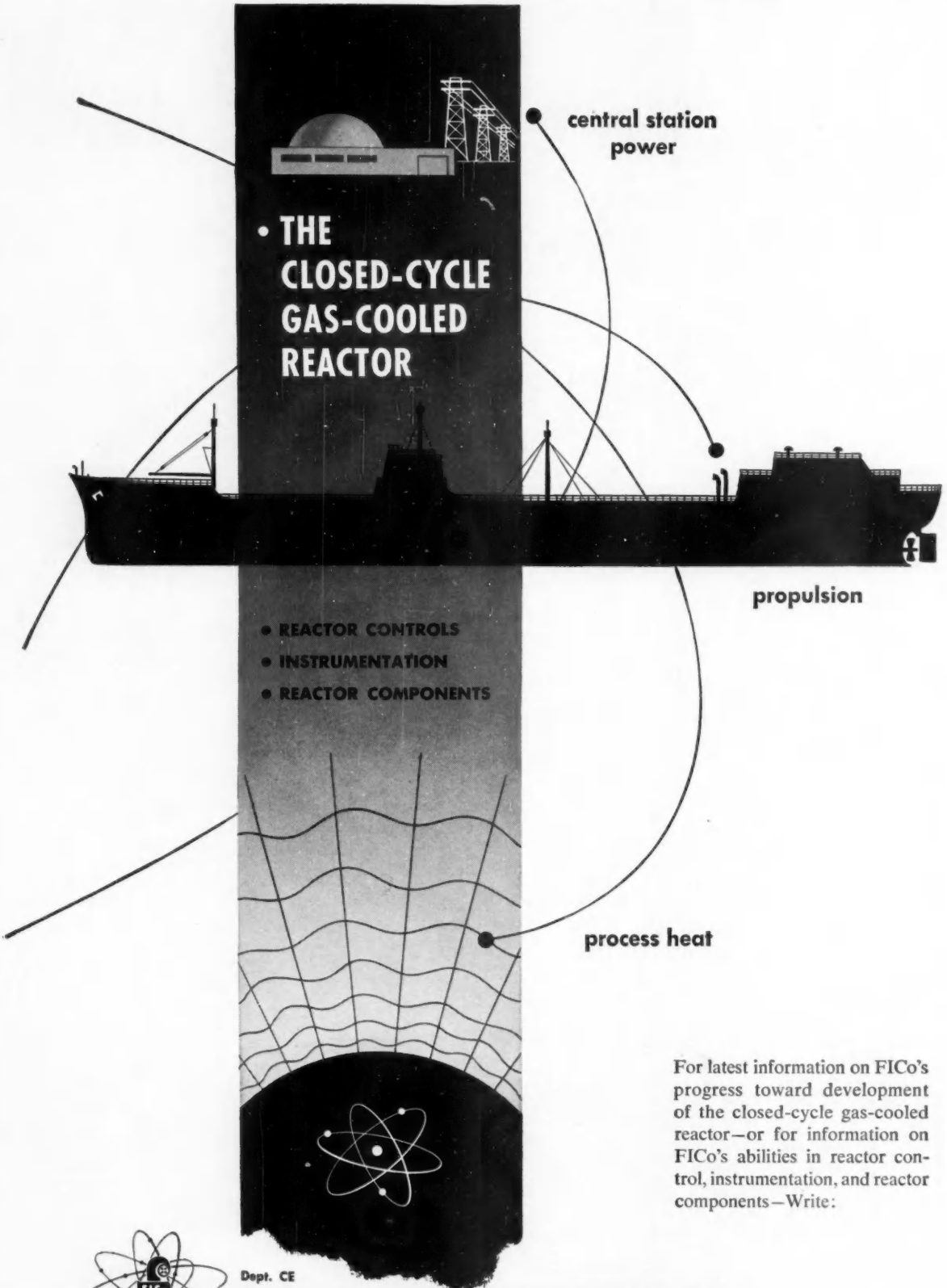


FIG. 2. Saturation in reactors in both legs allows last part of each input half-cycle to appear across demodulator transformer.



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L_1 to change the saturation level of the core, and thus the amount of the input voltage cycle absorbed across the amplifier. This effect shifts the position of the trailing edge of the line leg waveform by an amount proportional to the rate of approach to synchronism. The faster the generator is approaching synchronism, the greater the shift, so that the anticipation time remains substantially constant.

The trailing edge of the line leg waveform may be either advanced or retarded, depending on whether the generator frequency is approaching the line frequency from the high side or the low side. Figure 3 illustrates the action of the anticipation signal.

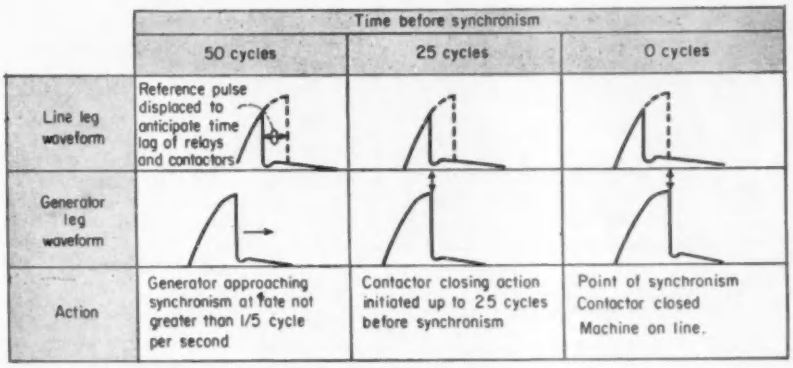


FIG. 3. Diagram illustrates action of the anticipation circuit.

Speed detection

The control relay also has a hold-off coil which, when energized, prevents the relay from closing. The hold-off signal is obtained from the tachometer generator by way of a bridge rectifier (not shown in Figure 1), and is thus always of the same polarity regardless of the polarity of the tachometer output voltage. The hold-off signal prevents the control relay from closing as long as the line-to-generator frequency difference is greater than $\frac{1}{3}$ cps.

Frequency-matching circuit

The frequency-matching circuit adjusts the speed of the diesel-driven generator so that the line-to-generator frequency difference is no greater than the $\frac{1}{3}$-cps value required by the phase-detector circuit. Speed is adjusted by pulsing the diesel engine governor motor.

Figure 5 is a simplified diagram of the frequency-matching circuit. A rotating contact is coupled to the shaft of the synchro motor so that its speed of rotation is proportional to the line-to-generator frequency difference. As each of the rotating contact arms contacts the center contact finger, capacitor *C4* is charged from rectifier *CR5* through resistor *R12*. As rotation continues, the contact arm contacts either the right-hand or the left-hand contact finger (depending upon the direction of rotation) to discharge capacitor *C4* through either the "raise" or the "lower" relay coil of the *A* relay. Discharging capacitor *C4* through either of the *A* relay coils causes the contact associated with the coil to close momentarily and thus energize that field coil of the governor motor which will raise or lower the speed of the diesel engine as required. The network *R13* and *C3* extends the pulse time of the *A* relay.

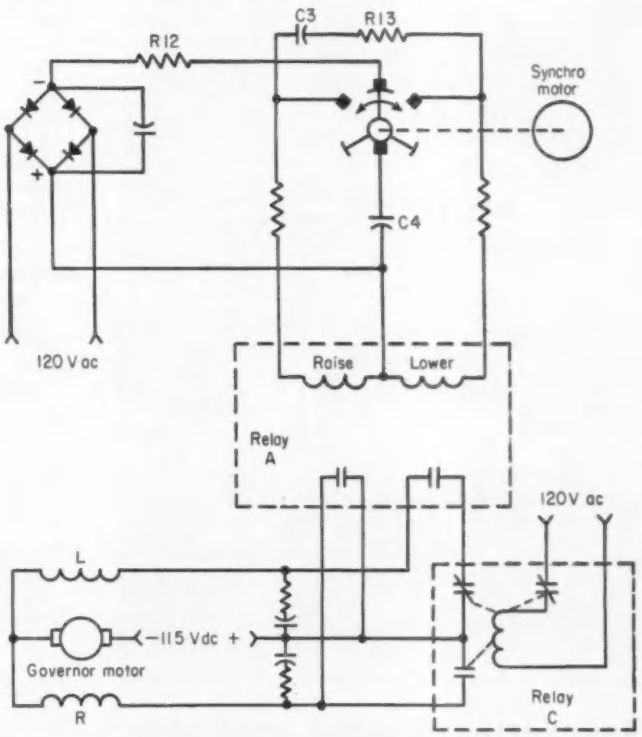


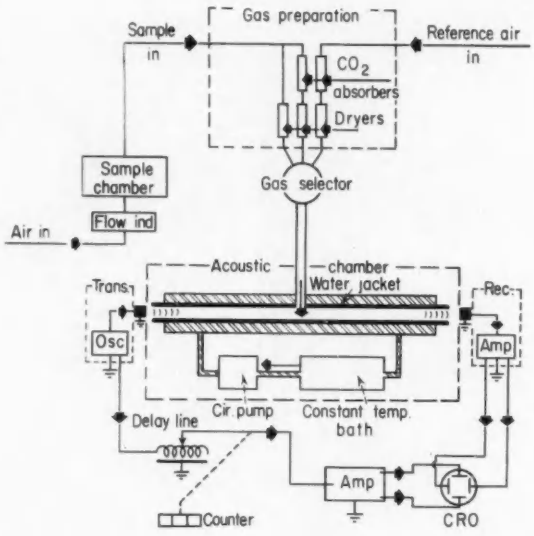
FIG. 4. Frequency matching circuit pulses diesel engine governor motor to raise or lower generator frequency.

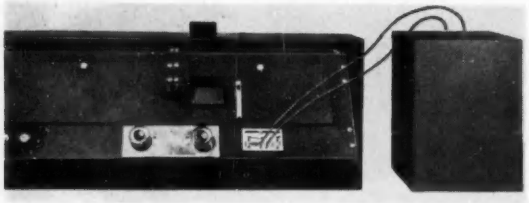
The C relay, a pneumatic relay with a delay action on both opening and closing, periodically pulses the "raise" field of the governor motor. This circuit is necessary because of the possibility of attaining a perfect frequency match with the generator out of phase with the line. Under this condition the synchro motor will stop rotating and the main circuit breaker will not close until the generator happens to drift within the 5-deg line-to-generator phase difference required by the phase detector circuit. By periodically pulsing the governor motor the generator frequency is made to drift through the point of synchronism so that the phase detector circuit may function.

NEW PRODUCTS

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GAS ANALYZER features exceptional range.

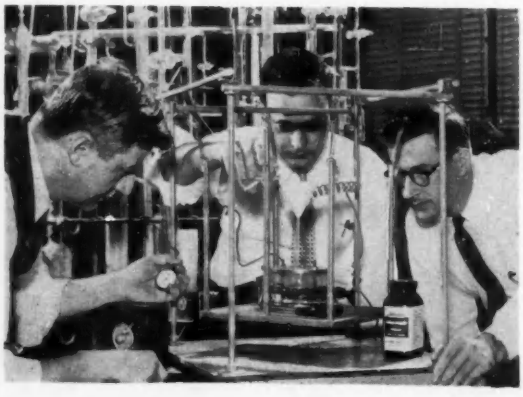
Exploiting the wide differences in sonic velocity, this new gas analyzer has achieved such measurable sensitivities as 0.005 percent oxygen in air and 0.00061 percent of hydrogen. The usual linking of high sensitivity with limited ranges of gas concentration does not exist in the sonic velocity method. The instrument's high sensitivity remains the same over the range of 0 to 100 percent.

Typical applications would be in monitoring gas mixtures by continuous or batch control, detection of minute amounts of harmful gases in pollution or personnel safety problems, vapor and gas chromatography, and in the study of certain isotope concentrations.

The instrument (see block diagram) contains a long tube in which the velocity of sound is measured. The gas sample is fed into this tube at its center and flows out at both ends, so that the velocity of flow neither increases nor decreases the rate of sound transmission. An oscillator generates sound waves at one end of the tube. These are received at the other end by a crystal transducer. An oscillation frequency of approximately 150 kc per second is used to achieve high sensitivity. The phase of the received signal is compared with that of the generating crystal, the phase shift being a precise measure of the change in velocity of sound propagation.

Called the Sonic Gas Analyzer, the unit was developed by Merck & Co. and tested in a variety of industrial and physiological applications. Single-chassis construction of the basic unit permits installation in industrial plants where other apparatus might be too delicate or too insensitive.—National Instrument Laboratories Inc., Riverdale, Md.

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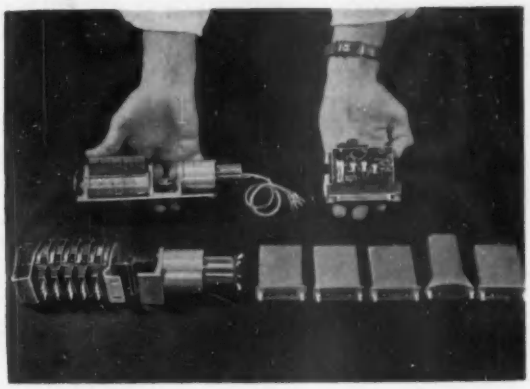
A new permanent magnet material, not yet commercially available, was recently unveiled by the General Electric Co. Credit for its development belongs chiefly to Dr. T. O. Paine, manager of GE's Measurements Laboratory, and his associates (photo, left). They have already produced, with ordinary iron, experimental magnets equal to the strongest commercial magnets now available, and believe that strengths ten times greater may be possible. The material is produced by aligning elongated, single-magnetic-domain, iron particles in a powerful magnetic field, and then compacting them under great pressure with a suitable binder. Choice of binder, ease of machineability, and absence of critical materials are added advantages.—General Electric Co., Schenectady, N. Y.

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AIRBORNE COMPUTERS shed weight.

A weight and size reduction program at the Westinghouse Air Arm Div. in Baltimore, Md., has achieved some remarkable results. A typical example is the instrument servo shown here. It consists of a servomotor, gear box, potentiometers, and an amplifier. Components in hands represent the equivalent of those in the foreground. Weight of the servo amplifier has been reduced from 33 to 4 oz. The new, all-transistorized amplifier replaces five molded units using vacuum tubes, and requires considerably less power. Further reduction size was effected by using fewer parts, 24 as against 39 in the original version. A new feedback loop corrects for any temperature effects on transistor characteristics.—Westinghouse Electric Corp., Pittsburgh, Pa.

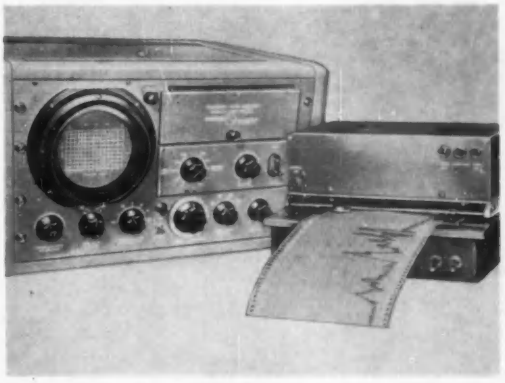
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SONIC ANALYZER identifies defects.

Shown here is the new improved version of Panoramic's Sonic Analyzer LP-1a. In addition to providing a logarithmic sweep range of 40 to 20,000 cps, the new model extends the linear sweep ranges of its predecessor by 200, 1,000, and 5,000 cps. The instrument is currently being used to identify mechanical and electrical defects and variations, to make fine adjustments, to test production models against standards, and to improve the design of rotating and oscillating machinery. An instant visual picture of waveform content, over a wide range, makes it easy to check frequency, position, and amplitude of any component, and to compare and analyze these data. An optional companion recorder yields a permanent record over extended periods.—Panoramic Radio Products, Inc., Mount Vernon, N. Y.

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LAB SPECTROPHOTOMETER saves time.

The Infracord, a low-cost double-beam infrared spectrophotometer, has been designed primarily for use by the organic chemist. Made to sell for less than $5,000, the new instrument features considerable versatility. It may be used for fast purity checks of raw materials, for recording the progress of an organic synthesis, and for precise quantitative analysis. In less time than is needed to determine a single property such as melting point, the unit will produce a permanent record giving a complete qualitative and quantitative picture of a compound. Compact and self-contained (requiring only a 120-volt, 60-cycle power supply), the Infracord scans a spectral range from 2.5 to 15.0 microns. —Perkin-Elmer Corp., Norwalk, Conn.

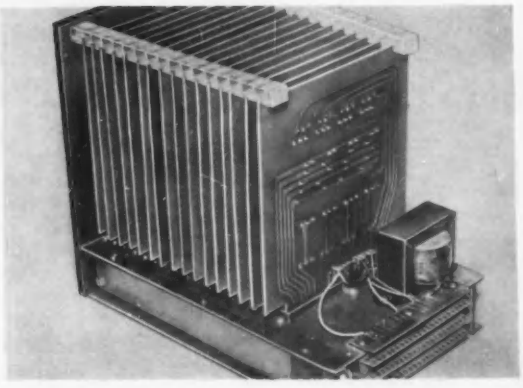
Circle No. 5 on reply card



DIGITAL COMPARATOR has many uses.

Designed to solve a number of digital servo problems, this compact unit compares any parallel binary signal with a similarly presented feedback signal, and produces an error-modulated ac output. Applications include table positioning from tape programmed instructions, wind tunnel control by positioning throat sections, machine tool control directed from computers, etc. Digital servo systems using such a comparator have certain advantages over analog systems. They can be readily programmed from tape or punched card information, and completely eliminate drift tendencies. Unit features a 100-percent transistorized error register and a pre-amp output of 5 volts at 1,600-ohms impedance.—Norden-Ketay Corp., Gardena, Calif.

Circle No. 6 on reply card



precision

PRESSURE REGULATORS

14 models to meet almost all industrial needs

Send for catalog

Now available from the Stratos Industrial Products Branch are two complementary lines of pneumatic pressure regulating valves.

The pilot-operated GOVERNAIRE: very high flows are regulated by small signals in these self-contained, pilot operated models. Up to 250 psi supply pressure, pipe sizes from ¼ to ¾ NPT.



Drift-free, lever set model 3500





The direct acting KENDALL: also available in a wide flow range, these force-balanced types are designed for operation at up to 250 psi supply pressure. Pipe sizes from ¼ to ¾ NPT.

STRATOS

INDUSTRIAL PRODUCTS BRANCH

A division of Fairchild Engine and Airplane Corp.

Route 109, West Babylon, N. Y.

NEW PRODUCTS

CONTROL DEVICES



PROXIMITY PICKUP CONTROL

The new Model 4901-RAC proximity pickup control unit shown above uses three-pin AN-type input connectors, and is said to be a refinement of the company's 4900 Series proximity transducer systems. The unit also features an ac convenience receptical at the output, wired for 115 volts, 60 watts. Vented cabinet measures 2⅜ by 4⅜ by 8 in.–Electro Products Laboratories, Inc., Chicago, Ill.

Circle No. 7 on reply card



STEPPING SYNCHRO

Using an electromechanical positioner to drive the rotor of a differential synchro in fixed increments of 1 deg, this new stepping synchro has an ac output that is synchronous with rotor position. Rotation of the mechanism is unlimited in both directions, and is operated by an electrical input pulse at any speed up to 60 deg/sec. The unit is suitable for use in complex directional or guidance systems where there is a need for servo actuation in precise rotational increments. –G. M. Giannini & Co., Inc., Pasadena, Calif.

Circle No. 8 on reply card

INDICATOR SWITCH

A new indicator switch that signals when a valve has completed its closing or opening cycle has recently been developed for use in aircraft and guided missiles. The switch is presently being used on propellant valves for malfunction analysis. According to the manufacturer, it is adaptable to any type of control where repeatability within plus or minus 0.001 in. is required. A sealed plunger, depressed by the valve stem, actuates the switch, thereby opening and closing control circuits. Two models are available: an SPDT type weighing 0.095 lb, and a DPDT type that weighs 0.19 lb.–Bridgeport Thermostat Div., Robertshaw-Fulton Controls Co., Milford, Conn.

Circle No. 9 on reply card



RUGGED RELAY

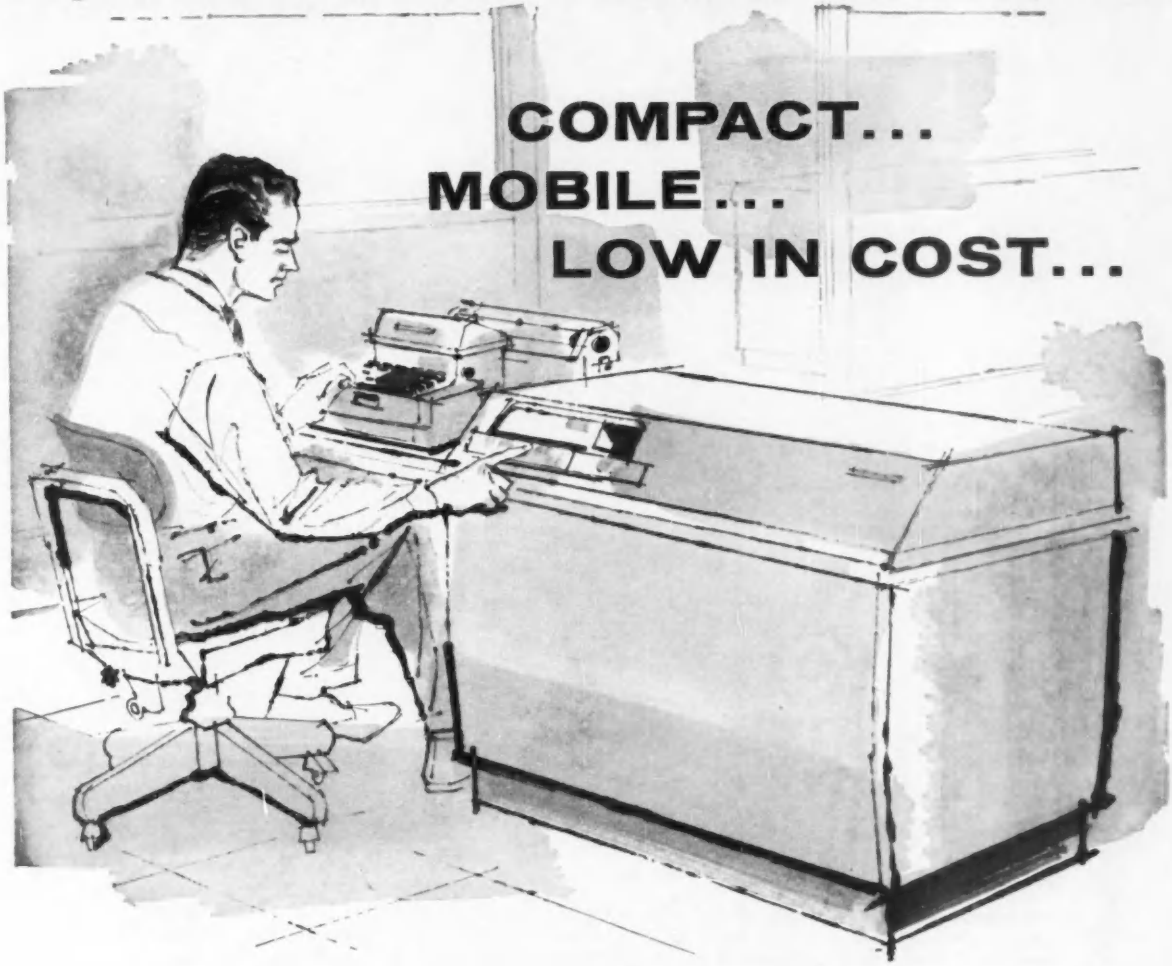
This hermetically sealed time-delay relay requires no warm-up and consumes as little as 1 watt. Designated Type EHS, the unit provides a fixed time delay of any value within its 0.1 to 10.0 sec range. Timing is accomplished by charging a condenser through a resistance from a regulated voltage source. This terminates with the conduction of a gas-filled tube and results in the relay operation. Unit is suitable for both commercial and military applications.–G. C. Wilson & Co., Huntington, W. Va.

Circle No. 10 on reply card

HIGH-SPEED RELAYS

For dc applications, a new high-speed relay incorporates a complete wiping action that eliminates bounce and

Royal Precision LGP-30 Electronic Computer



helps increase productivity of valuable engineers

Time-Saving. The LGP-30, a stored program computer, eliminates much detailed calculation and makes more time available for creative engineering.

Personalized. The LGP-30 brings high-speed electronic computation directly to the desk of the individual engineer. Most problems can be programmed completely right in his own office and followed through to the end — with modifications made from intermediate results as required.

Complements central computing installation. The LGP-30 can serve as a "satellite" to a central computing installation for those problems which are performed more effectively on a decentralized basis. New programming techniques permit the use of one code for both machines. Thus, programs may be prepared in the central computing facility directly from engineers' equations, and the computations done on the LGP-30.

Outstanding features of LGP-30

- Operates from regular wall outlet (110 volts AC).
- Requires no expensive installation . . . no external air-conditioning.
- Stored program computer.
- Unusually large "memory"—4096 words.
- Enters and reports numerical or alphabetical information by punched paper tape or keyboard.
- High-speed operation . . . finger-tip control.
- Lowest cost ever for a "complete" computer.
- Excellent service facilities available.
- Now being delivered.

For further information, write Royal McBee Corporation, Data Processing Equipment Division, Port Chester, N. Y.

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. . . quickly pinpoint design and engineering problems

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"Factory managers are using the time machines to find for the first time what is really going on in their plants.

" . . . For example Paper Mate Manufacturing Co., Burroughs Corp., Ethyl Corp., General Mills, General Motors, Ford are just a few corporations using high speed photography to stop time . . . freeze motion."

FASTAX cameras are the most widely used high speed motion picture and oscillographic cameras because they are the most versatile . . . have the widest speed ranges . . . offer the most complete line.

WRITE and see how high speed photography can help save engineering time . . . cuts down on development time because it enables your engineers to pinpoint problems more readily . . . helps picture the answer. Wollensak Optical Company, Rochester 21, New York.

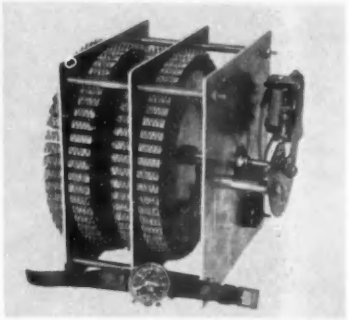


WOLLENSAK
OPTICAL COMPANY
ROCHESTER 21, NEW YORK

NEW PRODUCTS

chatter at normal operating voltages. Called the Type 120, this relay has an operating time as low as 2 millisec. Power required is anywhere from 0.25 to 2.5 watts, depending on the speed needed. Units are available hermetically sealed, dust covered, or open, with contact combinations from SPST to TPDT. Contact capacity is 1 amp inductive or 3 amp resistive at 115 vac or 29 vdc. Drop-out can be adjusted as high as 85 percent of pick-up.–General Automatic Corp., Mountain View, N. J.

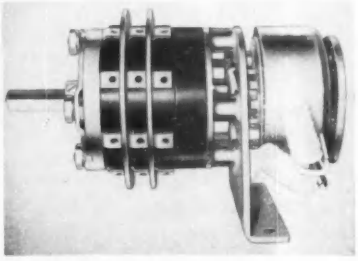
Circle No. 11 on reply card



HANDLES 1,252 COMPONENTS

The automatic sampling switch above is designed to sequentially test up to 1,252 two-terminal electronic components under actual operating potentials and extreme environmental conditions. By suitable connections, it will also handle 626 three- or four-terminal components. In the missile, computer, and other fields, such a switch can facilitate 100-percent component inspection.–Tensor Electric Development Co., Brooklyn, N. Y.

Circle No. 12 on reply card



HEAVY-DUTY SWITCH

This heavy-duty rotary switch, for the remote automatic or semi-automatic control of complex circuits, uses sol-



Microton hardness test typifies quality control measures that leave nothing to chance at Automatic Electric

STANDARDS THAT DETERMINE RELAY QUALITY

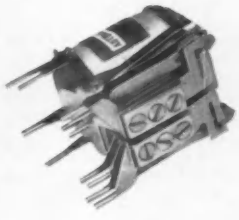
the ideal relay iron

Only soft, pure iron assures proper release, even after millions of operations.

In service, many relays get progressively slower to release, until finally the armature hangs up permanently. Excessively "hard" magnetic relay iron often is to blame. But in all Automatic Electric relays, the magnetic iron is so soft and pure that it saturates quickly, yet the flux dies out instantly. Even after millions of operations!

This improved relay iron is made and rolled to our own exacting specifications. Chemical analysis then makes certain that no magnetic capabilities have been lost. Annealing is rigidly controlled, and grain size and temper carefully checked. Elongation, hardness, permeability, and density tests further safeguard this pampered material. Result: not the *ideal* relay iron, but *the most nearly perfect iron available.*

This is no isolated example. Exhaustive tests prove that all our raw material is equally fine. It's one of the many reasons why Automatic Electric relays enjoy far longer life.



Series SQPC Relay for printed circuitry applications. *Write today for Bulletin RH-9, Automatic Electric Sales Corporation, Chicago 7.* In Canada: *Automatic Electric Sales (Canada) Ltd., Toronto.* Offices in principal cities.

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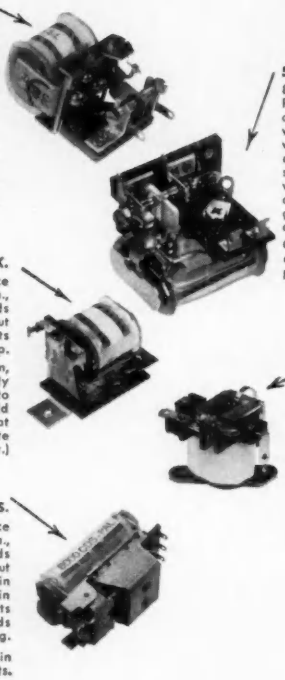
for **ENGINEERS, INVENTORS, RADIO AMATEURS, MODEL BUILDERS**

for **controlling toys, model boats, planes, cars, garage doors, electric fences, robot lawn mowers, iron-core politicians**

In addition to a variety of rather specialized sensitive relays developed for particular applications, Sigma also makes several "basic" types, among them the five DC sensitive SPDT types shown here. The unenclosed styles (illustrated) allow contact observation, and readjustment or cleaning in case of accident. They are also available in a variety of sensitivities, coil resistances, mounting styles and enclosures (open frame, dust cover or hermetically sealed; permanent or plug-in connections). One-at-a-time purchases can best be made from Sigma jobbers.

* * *

Complete catalog is available on request.



4F-8,000 S.
8,000 ohms, wt. — 2¼ oz. Price for one $6.00. Operates on 1.6 ma., releases on 0.75 ma., withstands 11 ma. continuously without overheating. Silver contacts rated at 2.0 amp. Withstands 10 g vibration while operating.
Radio Control Modelers' long-time choice because it is fairly sensitive, highly reliable, easy to mount and adjust. Lately overshadowed by the "26".

5F-8,000 SS.
8,000 ohms, wt. — 4¼ oz. Price for one $9.75. Operates on 0.35 ma., releases on 0.15 ma., withstands 15 ma. continuously without overheating. Palladium contacts rated at 0.25 amp. Too sensitive for applications where vibration will be encountered while operating. Other adjustments give secure contacts under 5, 10 or 15 g vibration.
Good for condenser time delay circuits and for holding during pulse trains.

41F-2,000 SK.
2,000 ohms, wt. — 2½ oz. Price for one $4.50. Operates on 4.0 ma., no specified release, withstands 22 ma. continuously without overheating. Tungsten contacts rated at 1.0 amp.
Keying relay giving clean, bounce-free pulses on normally open contact circuit at speeds up to 100 pulses per second. Coil should get at least 6 ma. signals from at least 150 volt supply. (Plate circuit, *not* cathode follower.)

11F-6,000 G.
6,000 ohms, wt. — 1 oz. Price for one $1.70. Operates on 2.9 ma., no specified release, withstands 13 ma. continuously without overheating. Silver contacts rated at 1.0 amp. Withstands 10 g vibration while operating.
Within its ratings, a good combination of high quality and low cost.

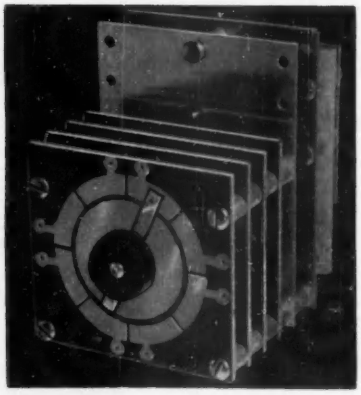
26F-8,000 CDS.
8,000 ohms, wt. — 2 oz. Price for one $8.50. Operates on 0.7 ma., releases on 0.4 ma., withstands 11 ma. continuously without overheating. Drop-out is held within 0.1 to 0.2 ma. of pull-on and within above limits. Palladium contacts rated at 0.5 amp. Withstands 5 g vibration while operating.
Designed especially for use in low power radio control circuits.

SIGMA

SIGMA INSTRUMENTS, INC.,
69 Pearl Street, So. Braintree, Boston 85, Massachusetts

enoids to drive the shaft through its cycle of contact positions. The indexing stroke of the solenoid device is matched to the degree of rotation between contact positions of the switch. It drives the rotor one position each time the solenoid circuit is closed by pushbutton or by a mechanical motion of the governed machine.—Electro Switch Corp., Weymouth, Mass.

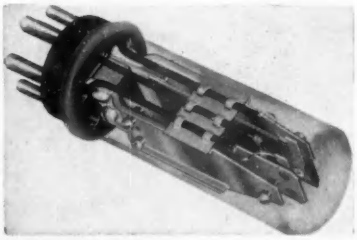
Circle No. 13 on reply card



SEQUENCE TIMER

This new sequence timer was developed for balloon instrumentation, but its features should interest designers in other fields, too. Commutator-type timing circuits are isolated from the motor assembly. Units can be supplied with from one to four decks, each deck accommodating from two to eight contacts. Weights range fror 3½ to 4½ oz, depending on the number of decks used. The power input at 6 vdc is 8 ma. Over a wide voltage range, speed regulation is within 1 percent.—Brailsford & Co., Inc., Rye, N. Y.

Circle No. 14 on reply card



RAPID RELAY

This positive acting nonmagnetic relay, the Capaswitch, uses a brand new

F-l-a-s-h!...from Transistor Center, U.S.A.

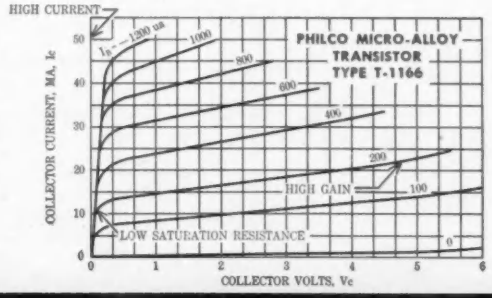


Announcing a new transistor class... The PHILCO Micro-Alloy Transistor (MAT)*



CHECK THESE UNEQUALLED FEATURES

- **Excellent High Speed Switching characteristics.**
- **Low Saturation Voltage (low impedance)**
- **Excellent high frequency amplification.**
- **Excellent low-level amplifier over entire frequency range from D.C. to Megacycles.**
- **Exceptionally Long Life (hermetically sealed)**
- **Permits high speed computer design with Fewer Stages.**



...world's first production transistor with exceptionally high frequency and high gain . . . plus low saturation resistance!

This newest development from Philco Transistor Center features the characteristic high frequency response obtainable with extremely precise base width control. Designed for low voltage operation, the new MAT transistor is especially well suited for high speed applications where low saturation resistance (reduced power consumption) is necessary.

To combine high gain at high currents with high frequency response, the new MAT transistor employs a gallium doped alloy junction for the emitter electrode.

A special short-alloying cycle, combined with precise electro-chemical production techniques (pioneered and developed at Philco Transistor Center for production of SBT), results in the micro-alloy contact for exceptionally high injection efficiency. This new process assures higher gain, and permits operation at higher current. Beta linearity is excellent over the entire range of operating currents . . . up to 50 milliamperes.

● ***Write for complete information** and specifications. Make Philco your prime source of information for high frequency transistor applications.*

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LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA



Bryant magnetic Drums

for semi-permanent storage of data in digital computers or for use as delay lines.

The outstanding performance of Bryant magnetic memory drums is attested to by their purchase by such outstanding companies as General Electric, Radio Corporation of America and Remington Rand.

Designed to your specific requirements, Bryant drums have a guaranteed accuracy of drum runout of .00010" T.I.R. or less. Belt drive or integral motor drive with speeds up to 100,000 R.P.M. or more. Capacities to 5,000,000 or more binary digits.

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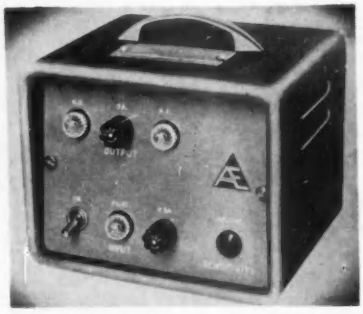
Bryant designs and manufactures electro-mechanical components for precision operation to your requirements, up to 200,000 R.P.M. If you have a problem in applying high speed rotating equipment to your product, write Bryant today.

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NEW PRODUCTS

actuating principle. In place of the usual electromagnetic coil, two unique electrostrictive ceramic capacitive units called Capadynes transfer the contacts. The electrostrictive ceramic instantaneously changes its dimensions when subjected to an electric field, bending in the same direction for both positive and negative polarity. One milliwatt second of energy, and a pulse duration as short as 5 microsec will activate the unit. A holding power of only 50 microwatts will keep contacts closed. Overvoltage protection is 150 percent.—Electric Machinery Mfg. Co., Los Angeles, Calif.

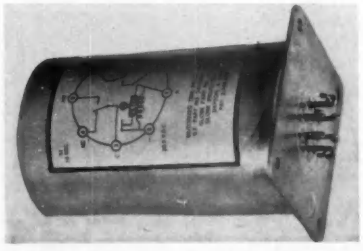
Circle No. 15 on reply card



PORTABLE CONTROL UNIT

Developed for use in a wide variety of electronic control systems, this standardized miniature control unit is essentially a very sensitive, heavy-duty electronic switch. It will control up to 500 watts of power, either delivered at 115 vac, 60 cps, or switched by its internal contacts. Minimum input impedance is 2 megohms. Rear mounted terminal strip provides maximum flexibility.—Autron Engineering, Inc., Los Angeles, Calif.

Circle No. 16 on reply card



MOTORIZED TIME DELAY

Shown is a new miniature motorized time delay switch that accommodates

Compact amplifier-voltmeter with millivolt sensitivity

High frequency extended range oscillator

Low-distortion, wide-band bridge type signal generator

BIG PERFORMANCE IN SMALL PACKAGES







Type 346 double-duty meter instrument. Serves simultaneously as vacuum tube voltmeter and highly sensitive a-c voltage amplifier.

METER RANGES: 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1.0, 3.0, 10.0, 30.0, 100.0, and 300.0 volts full scale. **ACCURACY:** ±3%, 20 cps to 1 mc, ±5%, 10 cps to 2 mc. **STABILITY:** ±1% at any line voltage between 105 and 130 volts ac. **INPUT IMPEDANCE:** 10 megohms – shunted by 24 uuf. **AMPLIFIER:** Maximum voltage gain 1000; maximum output voltage 1 volt. **OUTPUT IMPEDANCE:** 600 ohms resistive. **HUM AND NOISE:** One minor division max. **OVERLOAD:** Automatic overload protection. **POWER REQUIREMENTS:** 117 volts ±10%, 50-400 cps 40 watts. **SCALE:** Illuminated 4¼" damped meter movement. **DIMENSIONS:** 6½" high, 4¼" wide; and 7½" deep overall. Weight: 6½ lbs.

PRICE **$200***

Type 347 extended range oscillator featuring extended high frequency range, low waveform distortion, constant level output and remarkably small physical size.

FREQUENCY RANGE: 18 cycles to 1.1 mc in five overlapping ranges. **DISTORTION:** Total harmonic distortion of waveform less than 2/10 percent when operated into 10K ohms or higher load. **CONSTANT OUTPUT:** Output voltage constant to within ±½ db from 18 cps to 200 kc for any output over 0.1 volt. High range ±2 db. **OUTPUT LEVEL:** 10 volts open circuit. Maximum load current: 4 ma. rms. **OUTPUT CONTROL:** Logarithmic control calibrated in volts. **INTERNAL IMPEDANCE:** Approximately 400 ohms. **CALIBRATION ACCURACY:** ±2% (+1 cycle) from 18 cps to 210 kc, +10% to 1.1 mc. **STABILITY:** ± 0.3% for line voltage range of 105 to 130 volts, and ±0.5% for temperature range of 0 to 50°C. **HUM AND NOISE LEVEL:** 3.0 Millivolts or 60 db below output signals, whichever is greater. **DIMENSIONS:** 6½" high, 4½" wide, 6" deep overall. Weight: 6 lbs.

PRICE **$150***

Type 348 signal generator provides low distortion sinewave signals between the frequencies of 0.9 cps and 510 kc. Just right for design investigations of magnetic amplifiers, servomechanisms, computers and general laboratory and field use.

FREQUENCY CHARACTERISTICS

RANGES: 0.9 cps to 510 kc in six ranges. **STABILITY:** ±0.5% for frequencies up to 100 kc for line-voltage variations 105 to 130 volts and temperature within 0 to 50°C. **CALIBRATION ACCURACY:** ±2% (+½ cycle) above 10 cps; ±5% below 10 cps. **DISTORTION:** Less than 0.1% over most of the useable range rising to less than 0.3% at 30 cps.

AMPLITUDE CHARACTERISTICS

OUTPUT LEVEL: 50 volts, ±10% 2 watts or 40 ma maximum. **OUTPUT RANGES:** Continuously variable from 0 to 0.05V.; 0.5 volts; 5.0 volts; 50.0 volts. **STABILITY:** ±0.5 db referred to 1 kc over the entire frequency range. **OUTPUT IMPEDANCE:** At the 50 volt output range – 6 ohms in series with 1000 microfarad; 5 volt output range–6 ohms in series with 1000 uf; 0.5 volt range–55 ohms; 0.05 volt range–6.2 ohms. **POWER SUPPLY REQUIREMENTS:** 117 volts ac, ±10%; 50-400 cps, 110 watts. Fuse protection; 1.6 amperes, slow-blow. **DIMENSIONS:** 9-7/8" high, 7-5/16" wide, 10-11/16" deep overall. Weight: 19 lbs.

PRICE **$325***

** Price slightly higher in 50 cycle areas.*

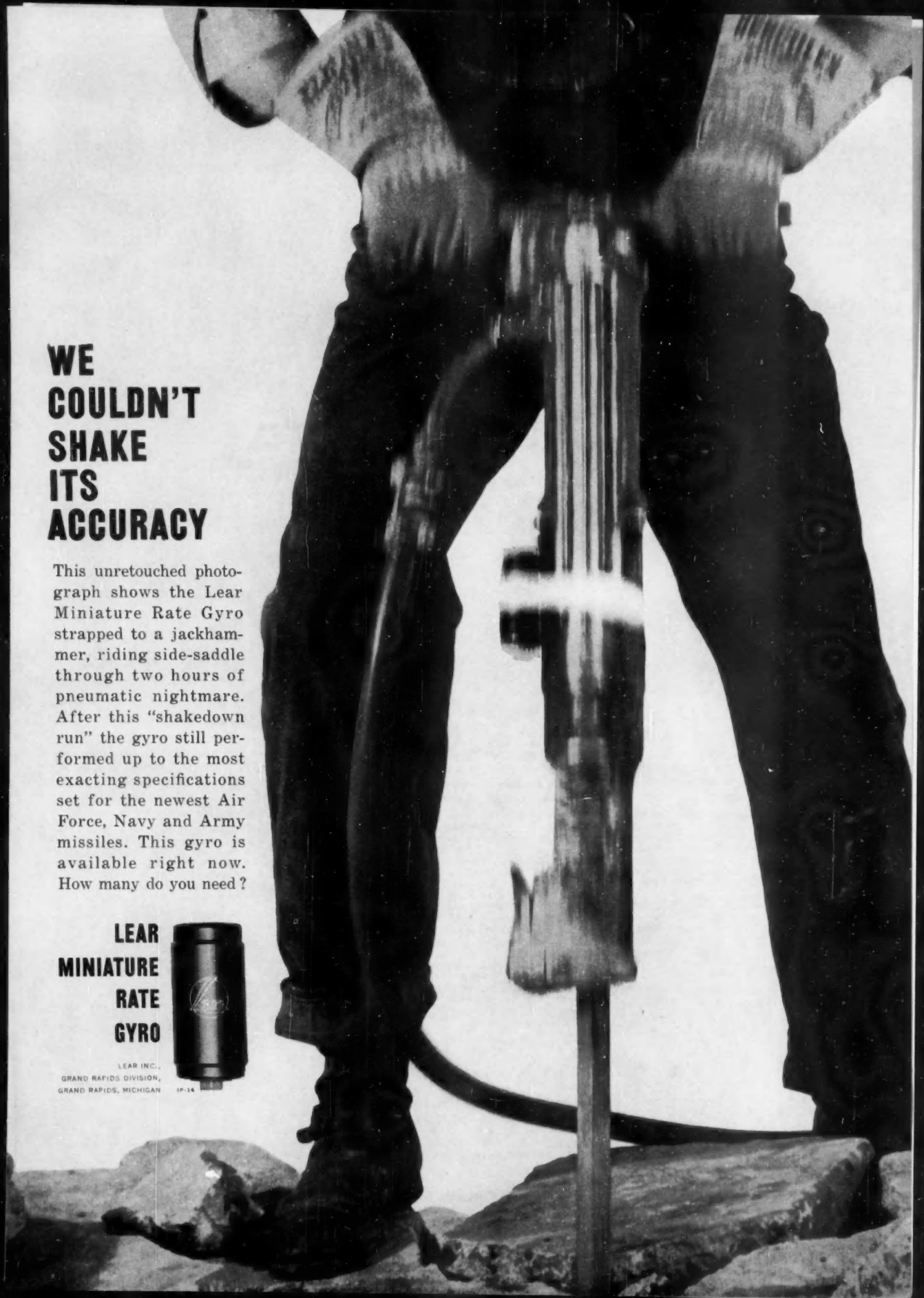
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WE COULDN'T SHAKE ITS ACCURACY

This unretouched photograph shows the Lear Miniature Rate Gyro strapped to a jackhammer, riding side-saddle through two hours of pneumatic nightmare. After this "shakedown run" the gyro still performed up to the most exacting specifications set for the newest Air Force, Navy and Army missiles. This gyro is available right now. How many do you need?

LEAR MINIATURE RATE GYRO

LEAR INC.,
GRAND RAPIDS DIVISION,
GRAND RAPIDS, MICHIGAN

IP-14

DATA

ON THE NEW
LEAR MINIATURE RATE GYRO



RUGGED AND DURABLE—It has been vibrated up to 20 G's and 2000 cps. and submitted to shock up to peaks of 110 G's without significant effect.

UNIVERSAL OUTPUT—Electro-magnetic pick-off supplies 6 volts, 400 cps. into a 10,000 ohm load at maximum rate input. Thus, units of different maximum rates may be interchanged without modification. Unit is also available including integral demodulator in a mounting base for applications requiring a DC signal output.

HIGH ACCURACY—Unit weighs only 1.2 pounds, measures only 1⅛" diameter by 3⅝" long, yet resolution, threshold and hysteresis closely approach zero rate.

MINIMUM "CROSS-TALK"—Patented design of torsion bar provides previously unrealized cross axis stiffness. Movements in insensitive axes virtually eliminated.

LOW THERMAL NULL SHIFT—Use of thermally compatible materials for all associated parts brings about new lows in the amount of null shift resulting from temperature changes.

UNIFORM DAMPING—Through selection and close control of piston and cylinder materials and damping fluid, the damping orifice varies with temperature to uniformly compensate fluid viscosity variation. Damping is thus maintained at .7 ± .3% critical throughout the operating temperature range of −65 F to + 165 F without the use of heaters.

VERSATILITY—Unit is available with either 26 or 115 volts, 400 cps., 3-phase or 115 volts, 400 cps. split single phase motor. Can be supplied for any maximum rate required. Unit is readily adaptable to requirements involving different signal outputs and damping characteristics. 2 and 3 axis packages also available.

LEAR

NEW PRODUCTS

up to 5 SPDT switching functions. This switch has a timing accuracy of plus or minus 5 percent of a total timing cycle, and meets military environmental requirements. Normal delays are from 15 to 30 sec with instantaneous reset when power is removed. Hermetically sealed, the switches operate on from 6 to 50 vdc. Power input is 15 watts for the motor, 7 watts for the clutch. At the end of the timing cycle the motor stops automatically, with switch position maintained by a clutch. Power interruptions during or after a timing cycle will result in automatic reset.—Globe Industries, Inc., Dayton, O.

Circle No. 17 on reply card

RESEARCH, TEST & DEVELOPMENT



PIRANI VACUUM GAGE

Designated Type 2203-03, this new one-to-four station Pirani vacuum gage gives direct continuous readings of the total pressure of condensable vapors and permanent gases on either of two scales. Scales cover 1 to 50 microns Hg, and 50 to 2,000 microns Hg. The instrument includes a new sensing tube that greatly reduces zero drift, one of the biggest problems in previous hot wire gages. This tube operates at a maximum temperature of 250 deg C. Carbon deposits on the filament do not change the tube's emissivity. Automatic voltage regulation provides for easier operation and permits use of a 0-to-10-mv recorder without constant operator attention.—Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 18 on reply card



GONIOMETER

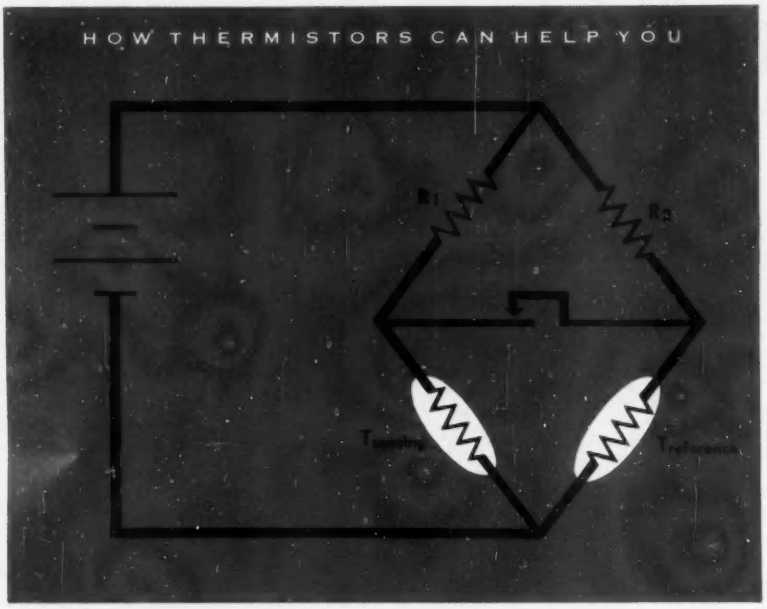
As a piece of production and inspection equipment, this newly developed goniometer provides an accurate means of measuring or adjusting the shaft angle of precision components. Its construction features a precision machine-engraved, 4½-in.-in-diam protractor which, by means of a vernier, can be read to within 1 min of arc. Graduations are accurate to within plus or minus 15 sec. The angle head turns in a tapered steel bearing, and means are provided to take up wear as required. The unit also provides for secure and accurate mounting for the component being tested. It will accommodate six different locating boss diameters ranging from 0.750 in. to 2.875 in. All standard size synchro and potentiometer mounting diameters fit without alteration, but adapters are available to accommodate special diameters.—Electro-Mec Laboratory, Inc., Long Island City, N. Y.

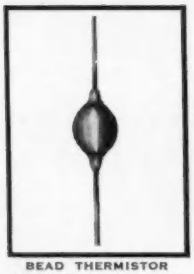
Circle No. 19 on reply card



RATIO METER

This Model 100 Transformation Ratio Meter is an rms voltmeter designed to read voltages of synchros and synchro systems rapidly, simply, and with a relatively high degree of accuracy. Indication is in percent





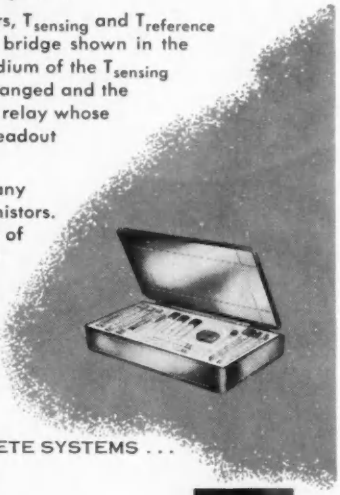
BEAD THERMISTOR
35 TIMES ACTUAL SIZE

detecting liquid levels with GLENNITE® thermistors

Engineers have discovered that versatile thermistors offer a unique, trouble-free method of determining liquid levels for many fluids. Accurate, instantaneous and dependable readings are obtained with only simple associated equipment.

GLENNITE Self-Heated Bead Thermistors, $T_{sensing}$ and $T_{reference}$ are used to regulate the balance in the bridge shown in the schematic above. When surrounding medium of the $T_{sensing}$ Thermistor is changed, its resistance is changed and the subsequent bridge imbalance activates a relay whose resultant signal can be transmitted to a readout or feedback device.

Liquid level detection is only one of many applications possible for GLENNITE Thermistors. To learn about others, send for your copy of the reprint, "How to Use Thermistors." It contains valuable technical information.



GLENNITE THERMISTOR KITS
THREE DIFFERENT ASSORTMENTS. EACH CONTAINS A VARIETY OF TYPES AND STYLES. THE PERFECT R & D TOOL . . . WRITE FOR DETAILS.

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Thermistor Division

Gulton Industries, Inc.

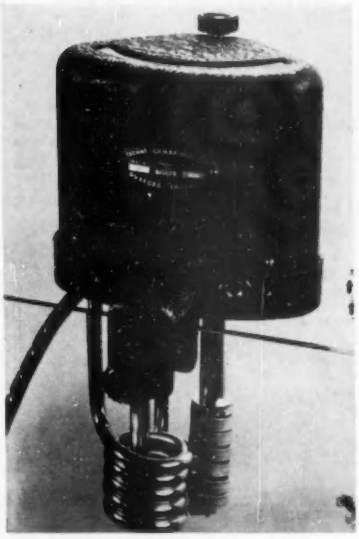
METUCHEN, NEW JERSEY

SEE US AT BOOTH #3032-31 AT MARCH I.R.E. SHOW

NEW PRODUCTS

deviation of synchro transformation ratio from the ideal ratio. The unit consists of a precision voltage divider, input switching, and an accurate expanded scale voltmeter.—Shasta Div., Beckman Instruments, Inc., Richmond, Calif.

Circle No. 20 on reply card



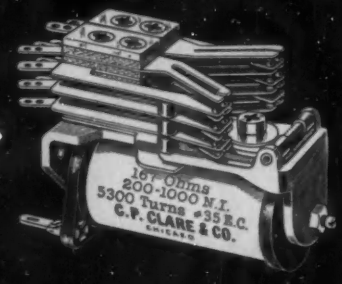
BATH CONTROL

Called the Tempunit, this device combines a self-contained heater, controller, stirrer, and circulator with a completely built-in pneumatic control system that is sensitive within plus or minus 0.05 deg C. A bimetallic helical temperature-sensing element operates a unique pneumatic capsule which receives its air supply through suction from the six-blade stirrer. A 1,000-watt tubular-type immersion heater permits rapid heating of an uninsulated 4-gal water bath from room temperature to set-point, without excessive overshoot.—Arthur S. LaPine & Co., Chicago, Ill.

Circle No. 21 on reply card

YAW-RATE TABLE

The Model 80A rate-of-turn table tests gyros and gyroscopic switches under extreme environmental conditions. An optional automatic rate programmer permits rates to be programmed as a function of time. The table is designed to subject a 10-lb load to rates of from 0 to 300 deg per minute, with rate fluctuation less



Do you have an unsolved "X" spot in your design?
...A place where you would put the "ideal" relay—if you had it?

TYPE J DESIGNS TO MEET WIDE DESIGN REQUIREMENTS

Standard Type J Relays

Twin contacts (Palladium standard). Rated current-carrying capacity: 4 amperes, 150 watts.

Power Type J Relays

Heavy-duty contacts riveted to springs. Code 18 (Silver). Rated current-carrying capacity; 10 amperes, 27½ volts d-c.

Type J Video Relays

For switching video and other high-frequency currents.

CLARE Type J Relays have been filling difficult "X" spots in industrial designs for more than a decade.

Processed of the most positive of all twin-contact designs, the CLARE Type J Relay has all the desirable features of a telephone type relay—yet greatly reduced in bulk.

Many basic design ideas have been improved by this relay—a CLARE original—whose wide acclaim has provoked a lot of imitators but never an equal—whose many distinctive features have provided an eminently satisfactory solution to many perplexing problems involving efficient, long-life relay operation.

Let us work with you to pick the best relay for YOUR important relay requirement. Address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare & Co., 659 Bayview Avenue, Toronto 17. Cable address: CLARELAY.

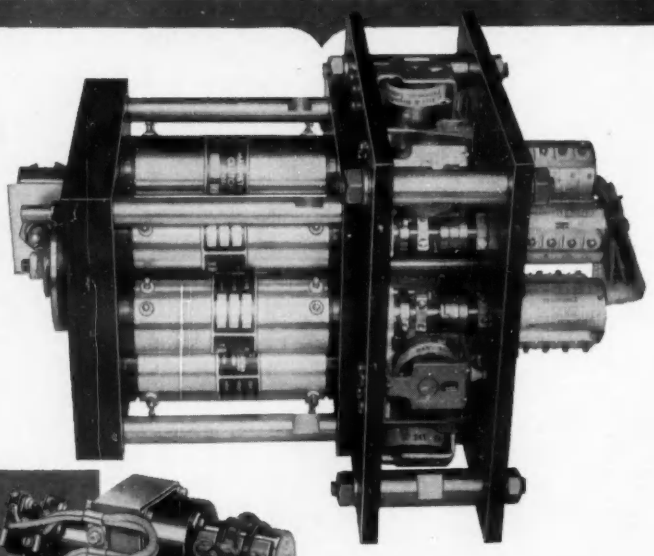
Write for Engineering Data Book and Bulletin 119

CLARE RELAYS

FIRST in the industrial field

BOWMAR

PRECISION ELECTROMECHANICAL ASSEMBLIES





FUEL CONTROL ASSEMBLY

1062 SPEED REDUCER

2216 LONGITUDINAL COUNTER

Illustrated above is a seven-stage servo storage unit designed and built by Bowmar Instrument Corporation in its Fort Wayne engineering and manufacturing plants. It is one of many such ultra-precision assemblies created by Bowmar for use in military and industrial control systems. Here is one more example of Bowmar's skill and experience in the control instrumentation field . . . one *more reason why more firms are using Bowmar's facilities for their most serious projects.*

Manufacturers of
PRECISION ELECTROMECHANICAL ASSEMBLIES, PRECISION SPEED REDUCERS, GEAR HEADS AND MECHANICAL COUNTERS

SEND FOR BROCHURE



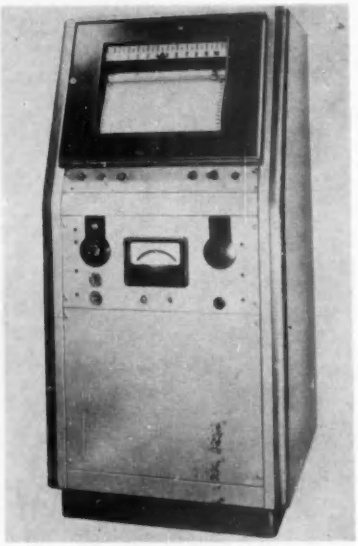
Bowmar INSTRUMENT CORP.

2200 PENNSYLVANIA STREET • FORT WAYNE, INDIANA

NEW PRODUCTS

than 1 percent. The control panel and amplifier can be remotely located and rack-mounted if desired.–Micro Gee Products, Inc., Culver City, Calif.

Circle No. 22 on reply card



RATIO PLOTTER

Automatic and continuous, the "T/ Plotter" is said to be able to save 50 to 75 percent of vibration testing time, eliminating data reduction and speeding test evaluations for design engineers. The unit plots a complete vibration transmissibility curve in strip chart form during the vibration test cycle. This permits immediate evaluation of equipment performance. A range of four full-scale settings permits plotting of ratios from 0-0.2, 0-1.0, 0-10, and 0-100. Ranges for the ratios' denominators are 0-20, 0-50, 0-100, 0-200, 0-500 millivolts, and 0-1, 0-2, 0-5 and 0-10 volts. Frequency response is within 2 percent from 5 to 2,000 cps, and within 2.5 percent from 2,000 to 4,000 cps. Chart speed is variable from 6 to 960 in. per hr in 16 steps.–Barry Controls Inc., Watertown, Mass.

Circle No. 23 on reply card

PUSHBUTTON pH METER

Called the Zeromatic, a new pH meter features automatic correction for electronic zero drift and rapid pushbutton control. It has a 0-to-14-pH scale

How to use a Wave Analyzer on an Ocean Wave

(or any low frequencies from 1/10th to 5 cycles per second)

A head-on attack on this problem will soon uncover the disconcerting fact that wave analyzers just don't come this big. Those of a more comfortable size generally operate on frequencies of five cycles per second and more.

But frequencies as low as 1/10th cycle per second – like earthquake waves, ship motion, and low-frequency vibrations of large machines and structures can be fed to conventional wave analyzers with completely satisfactory results. Magnetic tape recording provides an essential conversion step between.



Bell Aircraft Corporation's magnetic-recorder installation aboard the SS Mariposa for study of ship motion.



Speed change on the Ampex FR-100 is accomplished quickly and easily by a selector knob and switch.

Two Ampex FR-100 magnetic recorders were purchased and installed aboard the SS Mariposa for Bell Aircraft Corporation's study of ship motion at sea. The frequencies encountered were far below one cycle per second. These were recorded at the lowest tape speed on the recorder (1⅞ in/sec.). Reproducing the tape at the highest tape speed (60 in/sec.) multiplied the frequencies by 32. Recopying onto the second recorder and speeding up again increased the total speedup to 32 x 32 or a total of 1024. As an example, a frequency of 1/10th cycle per second became approximately 100 cycles per second and was easily separated and measured by wave-analysis equipment.

The Ampex FR-100 recorder has six standard speeds from 1⅞ to 60 in/sec. in the ratio of 1, 2, 4, 8, 16 and 32. Recopying accomplishes further multiplication by powers of two. Even a second recopying is perfectly feasible just in case you are interested in a frequency multiplication of 32,768.

Putting low frequencies onto magnetic tape requires an FM-carrier recording. On the Ampex FR-100 this is conveniently provided by plug-in amplifiers. Frequency response at 1⅞ in/sec. tape speed is 0 to 312 cycles/sec. At 60 in/sec. it is 0 to 20,000 cycles/sec. Besides its ability to record very low frequencies, FM carrier recording has the very desirable attribute of high instantaneous amplitude accuracy. Thus, the reproduced waves retain their original form very accurately through any amount of speedup.

If you have a problem that might be solved by data speedup, we would be pleased to furnish further information. Others of magnetic tape's remarkable capabilities will be the subjects of a continuing series of these bulletins. Would you like copies mailed direct? Write Dept. HH-3134.

MAGNETIC TAPE APPLICATIONS BY AMPEX

1

ONE OF A SERIES



Series FR-100



Series 800 Mobile and Airborne



Model FR-230 Digital



Tape Loop Recorder



Series FR-1100

INSTRUMENTATION DIVISION
AMPEX CORPORATION
FIRST IN MAGNETIC TAPE INSTRUMENTATION
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District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

FILTRATION *Engineered** TO MEET INDUSTRY'S NEEDS

CUNO

The ONLY Line that offers You Several Distinct Types of filter Media . . . The RIGHT Choice for Every Requirement

AUTO-KLEAN

METAL EDGE TYPE

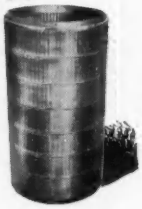
Continuously cleanable. Combine small size, high flow rates and low pressure drop. A wide range of models and sizes with capacities to 4000 gpm and filtrations as fine as 40 microns.



FLO-KLEAN

WIRE-WOUND

For low-viscosity, high volume (up to 15,000 gpm) filtration. Filtration from .0025″ to .030″. Filters are completely automatic, continuously self-cleaning without loss of backwash fluid.



MICRO-KLEAN

FIBER CARTRIDGE

New white cellulose cartridge for 5-micron filtration wherever clarity, purity and taste are essential. Wool cartridge for a wide range of 10 to 70 micron applications including compressed air. Housings for flow rates from a few gph to hundreds per minute.



PORO-KLEAN

POROUS STAINLESS STEEL

Cartridges and special forms. Combine extreme heat and corrosion resistance, high tensile strength and very fine filtration (down to 5 microns, standard). Tests prove no contamination from particle discharge.



*Because no *one* type of filter is best for every need, Cuno – and *only* Cuno – offers you a truly complete line that includes *several* distinct types of filtration media. And because every filtration system must be specified and engineered to the individual job requirements, Cuno also offers you a complete application engineering service through the Cuno Systems Engineer. Conveniently located in your area, one of these specialists is ready and qualified to help select the filter type and model exactly right to solve your problems.

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EDGE-TYPE, WIRE-WOUND, FIBER CARTRIDGE and POROUS METAL FILTERS

Filtration Engineers in Principal Cities

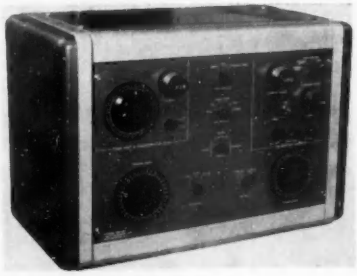
range and two millivolt ranges: 700-0-700 mv and the extended 0-1,400 mv range. The latter is particularly useful for oxidation-reduction titrations. Mirror-backed scales eliminate parallax, thereby minimizing reading error. Readings are accurate to within 0.1 pH unit and reproducible to within 0.02 pH. The instrument also uses a unique standby circuit that eliminates warmup.–Beckman Instruments, Inc., Fullerton, Calif.

Circle No. 24 on reply card

DC METER CALIBRATOR

An improved Mode M100A-20 Meter Calibrator provides dc from 0 to 1,000 volts at 0 to 200 ma with 0.01 percent long-time stability, 0.01 percent line and load regulation, 0.2 millisecond response time, and less than 0.01 ohm output impedance. High-gain chopper amplifiers constantly compare output voltage with an internal standard cell. Direct-reading calibrated dials permit instant selection of the desired output voltage. Uses include laboratory and production meter calibration, research, etc.–Kay Lab, San Diego, Calif.

Circle No. 25 on reply card



SYNCHRO TEST SET

This compact test set simplifies the rapid and accurate testing of all types of synchros. It measures electrical error, null, transformation ratio, and phase shift in accordance with appropriate military specifications. Features include direct-scale readings, and a 2-deg range for electrical zeroing from the control chassis. On synchro shaft positioning, the unit has an accuracy within 15 sec of arc, the error being noncumulative. On synchro bridges, maximum error is only 10 sec of arc.–Theta Instruments Corp., East Paterson, N. J.

Circle No. 26 on reply card

VARITROL® automatic variable speed

SAVES MANPOWER

IMPROVES PRODUCT

INCREASES OUTPUT

Now, by controlling speed with the Varitrol as a component of the U. S. Varidrive motor, speeds can be *automatically* changed in response to a signal *without* human attention for precision-control operations. At right is shown just one of the many ways in which Varitrol automatic control of U. S. Varidrive motors can be used for automatic production control. An educational booklet, edited by variable speed engineers, illustrates with applications this method of greater production of more goods and services at lower cost and astounding man-hour savings. Write today for your complimentary copy.

SYNCHRONIZATION

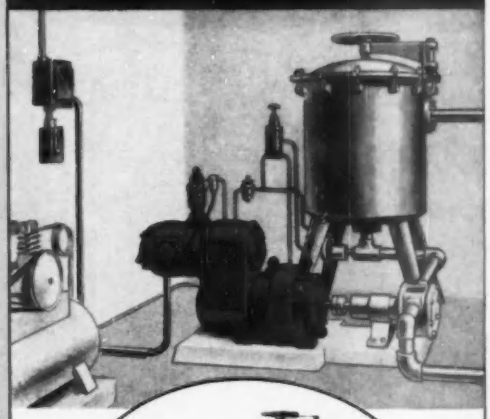
CONSTANT VELOCITY

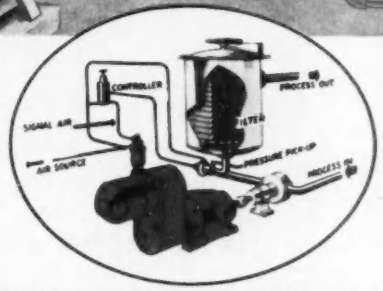
WEIGHT CONTROL

HUMIDITY CONTROL

HEAT CONTROL

PRESSURE CONTROL





A Varidrive-operated pump runs at high speed with clean filter to obtain maximum flow. As filter clogs, pressure pick-up signals Varidrive which gradually slows down to limit filter back-pressure. When filter is clean, speed automatically increases.



U. S. VARIDRIVE WITH VARITROL®

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☐ Send Varitrol Automation Booklet No. 1882
☐ Send U. S. Varidrive Booklet No. 1797

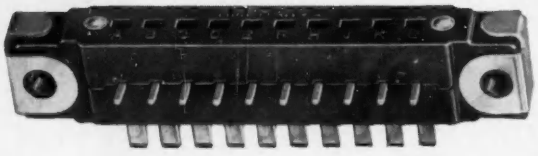
Name_____

Company_____

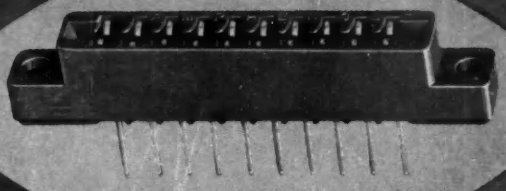
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AMPHENOL



New 133 Series Plugs and Adapters



143 Series Receptacles for Boards or 133 Series

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CONNECTORS

Prin-cirs are unlike any other printed circuit connectors! Engineered to the exacting requirements of major equipment manufacturers, utilizing superior gold-plated contacts, featuring high-strength bodies molded of diallyl phthalate, AMPHENOL Prin-cirs provide *increased* reliability for printed wiring connections. Prin-cirs are available in two series:

RECEPTACLES Heart of these connectors is a new contact with a circle lip entrance for good wiping action and a long spring base. It can't be 'set' or overstressed when used with standard boards, has low millivolt drop and long life. 143 series receptacles of 6, 10, 15, 18 and 22 contacts with four tail styles.

PLUGS AND ADAPTERS Newly available, these mate with the Prin-cir receptacles. May be used for building modular units, right angle stack-ups or cable plug-ins. Molded nylon guide pins are a strong feature. 133 series; 10, 15, 18 and 22 contacts with five tail arrangements.

For Printed Circuits, as for every major component use, make contact with AMPHENOL!

AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois



NEW PRODUCTS

PRINTER-PLOTTER

BEPOC (Burroughs Electrographic Printer-Plotter for Ordnance Computing) is believed to be the first readout device to match the speed of an electronic computer. At present, one such model is being used to process ballistic missile-test data at Aberdeen Proving Ground, Md. The unit operates as a high-speed page printer in translating the computer's words into printed plotting positions and alphanumeric information on continuous rolls of ordinary page-width paper at a speed of 300 plotting points per sec. A laboratory model of the device has printed 5,000 characters per sec serially in tests.—Burroughs Corp., Detroit, Mich.

Circle No. 27 on reply card

MEASUREMENT & DATA TRANSMISSION



SERVO ACCELEROMETER

The Model 4112 Linear Servo Accelerometer, photo above, incorporates a high-gain electromechanical amplifier in closed-loop operation, for the precise measurement or control of linear acceleration over the range of 0 to 25 cps. The device is well-suited for aircraft and missile applications where rugged construction and a high degree of accuracy are required. Similar units are now being used in an airborne inertial stabilizer, and in an inertial instantaneous vertical velocity indicator. Other uses include calibration of both linear and angular



For **quickest service** in solenoid valves, write for Skinner's Nationwide Stock List

The Skinner Nationwide Stock List covers the most universally applied Skinner Solenoid Valves for air and hydraulic service. All the valves listed are carried by every Skinner Stocking Distributor in the U. S. From his stock, your own local distributor can quickly meet your requirements. So for your own convenience, we urge you to write for this nationwide stock list of Skinner Solenoid Valves.

Skinner Stocking Distributors are located in all key industrial areas. If you have a solenoid valve problem, talk to the one nearest you. Tell him your requirements in regard to port sizes and locations, voltages, pressures, temperature conditions, capacities and mountings. Let him show you how easily he can select the valve you need.

For complete information on Skinner's line of exceptionally long-life 2-, 3- and 4-way valves, write us or contact a Skinner representative. Write Dept. 343.

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NEW BRITAIN CONNECTICUT

105 EDGEWOOD AVENUE

THE CREST OF QUALITY



PROBLEM #3

Design a miniaturized 400 cycle power transformer for airborne operation, with a three phase primary and three secondaries: three phase, two phase and single phase.
Transformer to operate in an ambient temperature ranging from —55° C to +85° C. The maximum allowable temperature rise to be 40° C over ambient. Transformer to operate at altitudes up to 50,000 feet. Dimensions cannot exceed 5" high, by 2¼" wide, by 2½" long, nor can the weight exceed 2½ pounds. The primary source to be 115V, 400 cps, three phase. The three secondary loads to be (a) 30V, three phase, at 1.8A with .5 lagging power factor, (b) 30V, single phase, at .4A with .7 lagging power factor, and (c) 115V, single phase, in quadrature with (b) ±5°, at .47A with .7 lagging power factor. Secondaries (a) and (b) to be loaded continuously with (c) loaded intermittently. All secondary windings to be ended in four terminals. Construction to be in accordance with applicable parts of MIL-T-27, Grade 1, Class A. The above are given as maximum dimensions and minimum performance requirements, greatest possible improvement in size, weight and performance requested.

SOLUTION BY PEERLESS

Power Transformer, three phase, 400 cps to one phase, two phase, and three phase
Construction: Grade 1, Class A, to MIL-T-27
Ambient Temperature Range: —55° C to +85° C
Temperature Rise: 35° C
Primary: Three terminal, three phase, 115V, 380-420 cps, per phase
Secondaries: Total of four terminals
(a) 30V, three phase at 1.8A and .5 lagging power factor. Continuous duty.
(b) 30V, single phase at.4A and .7 lagging power factor. Continuous duty.
(c) 115V, single phase, at .47A, .7 lagging power factor and in quadrature with (b) within ±1°
Weight: Two pounds
Dimensions: H: 4-1/32" + 1/2" seven terminal header; W: 2-1/32"; L: 2-9/32"

Experience in designing transformers to meet and exceed the most unusual and difficult specifications gives the Peerless engineering staff unique qualifications that speed the solution of every transformer problem. This background combines with rigid quality controls and advanced production techniques throughout the Peerless plant to achieve uniform quality and dependability in all Peerless products.

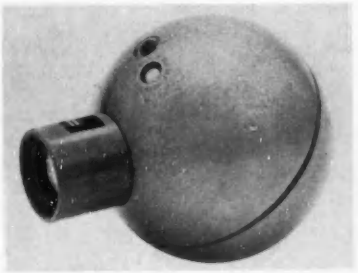
Consult Peerless for the best solution to your quality transformer requirements.

PEERLESS **Electrical Products** A DIVISION OF ALTEC LANSING CORPORATION

1515 S. Manchester Ave., Anaheim, Calif. • 161 Sixth Avenue, New York 13, N.Y.

accelerometers and measurement or control of "g"-level on a centrifuge.—Donner Scientific Co., Concord, Calif.

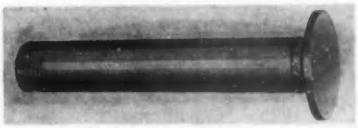
Circle No. 28 on reply card



ELECTRONIC EYE LOGGER

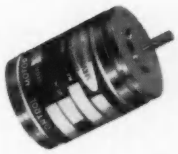
Shown is the receiver sphere of a new electronic eye checking-logging device that is now being used for photoelectric counting, door opening units, and other types of remote control. This particular unit houses the light sensitive "eye", an amplifier, and a relay. Operating components are housed in the upper half of this sphere. The projector sphere contains a lamp and transformer. A calibrated sensitivity control, adjustable from outside the housing, permits locating the spheres close together or far apart. An easily adjusted lens focus system provides for focusing the light paths of both receiver and projector to allow a small object to break the light beam a few inches or a few feet away from the lens.—Basic Controls Co., Culver City, Calif.

Circle No. 29 on reply card



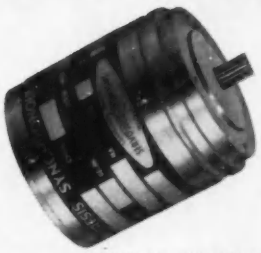
FOR LIQUID METALS

A line of temperature-compensated transducers, designed to sense the level height of liquid sodium and other liquid metals at temperatures to 1,300 deg F, has recently been developed. These units have no moving parts and are made in the form of a probe containing a hollow bore sealed at the top. They can be welded into the top of a receptacle with the probe extending downward. The rise and fall of the liquid metal in the bore of



SERVO MOTORS:—

For wide ranges of voltage and impedance—high peak voltages without damage to motor—inherent damping or variable magnetic damping.



HYSTERESIS SYNCHRONOUS:—

Compact—reliable operation at −55° C. Up to 31 watts output and 50% efficiency in 1¾" diameter. Smaller frame sizes available.



UNCASED MOTORS:—

Both hysteresis and servo types can operate without housing. Saves weight and space in special built-in applications.



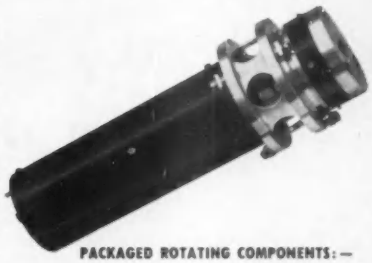
GEARHEAD MOTORS:—

Rugged, reliable. Single housing. Integral slip clutch—low backlash. Wide range of standard ratios readily available.



MOTOR TACHOMETERS:—

High precision and damping tachometers. Linearity up to 0.05%, nulls to ±1 MV, scaling error ±0.05% from −55° to +75°C.



PACKAGED ROTATING COMPONENTS:—

Tailored combinations of motors, gearheads, potentiometers, synchros, etc.

"Special" motors are our business

Every motor we make is "special"...designed to meet your most exacting requirements and produced with the precision workmanship needed to satisfy the most stringent specifications.

The few representative motors shown above will give you some idea of our wide experience in the field of precision motors. Our intensive investigations in the areas of miniaturization and the effects of high temperatures are reflected in all our products.

What the photographs do not show are the hidden quality materials standard with SMI...nickel steel laminations, ABEC Class 5 stainless steel bearings, teflon lead wire, heavy silicone and teflon magnet wire, stainless steel shafts, and many others.

So, you can see it's to your advantage to consider Servomechanisms, Inc., as your source for high performance precision motors. Write for our Motor Catalog which gives full details.

SERVOMECHANISMS SMI INC.

MECHATROL DIVISION

625 Main Street • Westbury, L.I., N.Y. • EDgewood 4-6500

Western Regional Office

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HAVE YOU CONSIDERED THE BENEFITS



OF LOW COST B-T LABS CLOSED CIRCUIT TV FOR YOUR ORGANIZATION?

Lower production costs, improved quality control and inspection, smoother traffic flow, less labor waste, better safety conditions are just a few of the benefits offered by B-T industrial TV products.

The B-T Observer TV camera offers effective closed circuit television at low cost. Now, with the exclusive B-T AUTOMATIC LIGHT COMPENSATOR, the camera operation is rendered completely automatic further broadening its scope in industrial applications.

The Automatic Light Compensator automatically handles light variations as great as 150 times, i.e., 5 to 750 foot candles or vice versa. Despite wide and frequent changes in light intensity at the subject, it is now possible to observe a constantly clear, well-defined image on the viewing screen. This eliminates the need for manual or remote adjustment of lens iris or camera controls.

B-T industrial TV extends the range of your vision beyond your office, or lab to remote, hazardous or inaccessible locations. Here are some industrial TV systems, now in operation, using the B-T Observer:

- **A textile manufacturer** links the design and embroidery machine department located on different floors for quality and process control.
- **A Pennsylvania steel mill** watches furnace and rolling operations. Exclusive B-T Automatic Light Compensator overcame problem of sharp changes in light intensity at the subject.
- **A midwestern cement manufacturer** checks composition and flow of slurry into a kiln, preventing costly damage due to congestion. Saves $36.00 a day in manpower and material.
- **A lumber company** prevents log jam damage, also identifies wood types (proof of the clarity of the TV picture) by observing the bark structure.
- **A Los Angeles utility** has a multi-camera setup for flame control.

A complete industrial TV system – B-T Observer TV camera, with f1.9 lens, B-T Automatic Light Compensator, one monitor (receiver), and cable – can be installed, ready to operate for under $2,500.

There's a qualified B-T distributor in your area with complete engineering facilities to serve your specific needs. For further information write to Dept. CE-3

BLONDER-TONGUE LABORATORIES, INC.

9-25 Alling Street Newark 2, N.J.

The largest manufacturer of TV Signal Amplifiers, UHF Converters and Master TV Systems

NEW PRODUCTS

the probe is sensed by the pickup coil, and with the aid of appropriate circuitry can be used for recording, indicating, or controlling liquid level. –Crescent Engineering & Research Co., El Monte, Calif.

Circle No. 30 on reply card



SIGNAL CONVERTER

The three-channel instrument shown here is designed for telemetering applications. Actually, the unit is a modification of an earlier low-level oscillographic recording device. It converts signals from 400-cps transducers to 0-to-5-volt dc for telemetering inputs. Conversion by a crystal diode demodulator eliminates all amplifiers from the signal circuits, assuring gain and zero stability. Linearity of the demodulated signal output is within 0.5 percent.–Dynalysis Development Laboratories, Inc., Los Angeles, Calif.

Circle No. 31 on reply card



INSTRUMENT TRANSLATOR

This compact transistorized device solves the problem of how to substitute variable reluctance electromechanical pickoffs for potentiom-

TEST RECORDING INSTRUMENTS

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oscillographs
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amplifiers
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MIDWESTERN MI INSTRUMENTS

41st and Sheridan Road Tulsa, Oklahoma



6000 PSI

wide range, high-flow regulator

maintains high degree of accuracy with regulated pressures from 0 to 5000 psi!



performance features:

- Normal inlet pressure of 6000 psi!
- Wide adjustment range of 0 to 5000 psi with extreme sensitivity!
- Burst — 15,000 psi!
- Maximum required handle torque 30 inch lbs. due to planetary gear system in handle!
- Adaptable for use with air, nitrogen, helium and gaseous oxygen!
- ¼" tube straight thread gasket seal bosses per AND10050!
- Also available in AND10053 ¼" pipe thread!
- Internal valve and filter are removable without disturbing spring, diaphragm structure!
- Internal relief valve adjustable over entire outlet pressure range!
- Internal 5 micron filter!
- Bubble-tight shut-off!
- Adjustable mounting!

Please send me engineering data information on:

Part 110700—Air, nitrogen, helium. _____

Part 111700—Gaseous oxygen only. _____

APCO

ACCESSORY PRODUCTS CORP.

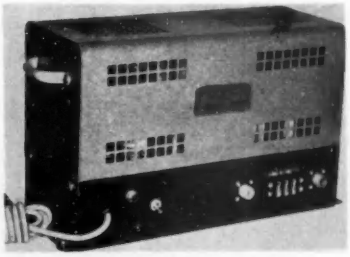
Dept. C3, 616 W. Whittier Blvd.

Whittier, Calif. Phone: OXford 3-3747

NEW PRODUCTS

eters in aircraft and missile systems without adding considerable size and weight to the electrical equipment. Called an Instrument Translator, the device receives power from the system power supply, whether ac or dc, and, when connected with a suitable ac sensing transducer, produces a dc or ac signal proportional to the physical changes sensed by the transducer. Small size and light weight combine to make the unit suitable for all types of aircraft and missile systems. Various models are produced to operate meters, recorders, hydraulic valves, servo motors, etc.—Crescent Engineering & Research Co., El Monte, Calif.

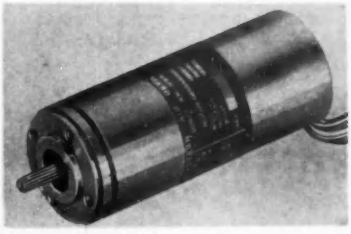
Circle No. 32 on reply card



TRANSIENT CONVERTER

Developed for use with turbine-type flowmeters, this new transient converter accepts a sinusoidal input signal of varying frequency and provides either an analog output for recorders and oscillographs or a digital output to counters and computers. Input frequency range is from 0 to 600 cps, operating from a 500-ohm source impedance. Output is a 0-to-100-mv analog signal or a 10-volt positive pulse to digital devices. Unit features plug-in subassemblies.—Fischer & Porter Co., Hatboro, Pa.

Circle No. 33 on reply card



RUGGED AND PRECISE

Featuring a plus or minus 0.5 percent linearity, this little unit consists of a high-performance, low-inertia, ac

solve many difficult control problems...use

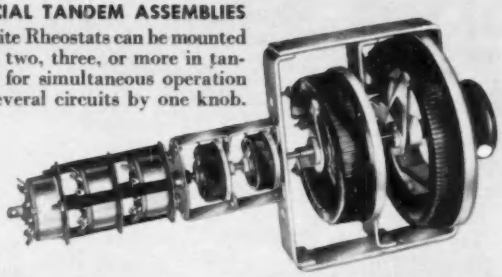
OHMITE®

RHEOSTATS

with special features

Ohmite offers not only a line of *standard* rheostats but also rheostats with a wide variety of *special features*. Illustrated are only a few. All have the distinctive Ohmite design features: smoothly gliding metal-graphite brush; all-ceramic construction; insulated shaft and mounting; windings permanently locked in place by vitreous enamel. You will find the special rheostat feature you need in the dependable Ohmite line.

SPECIAL TANDEM ASSEMBLIES
Ohmite Rheostats can be mounted with two, three, or more in tandem for simultaneous operation of several circuits by one knob.

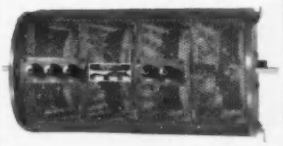




BUSHINGS FOR SPECIAL THICKNESS
Extra-long bushings and shafts for panels up to 2" in thickness. Seven bushing lengths.



SCREW DRIVER SLOT SHAFT
Shaft ends slotted for operation with a screw driver where few adjustments are needed.



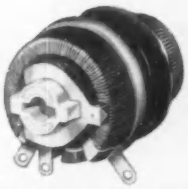
VENTILATED CAGES
Prevents mechanical injury to rheostat or human contact with electrically "live" parts.



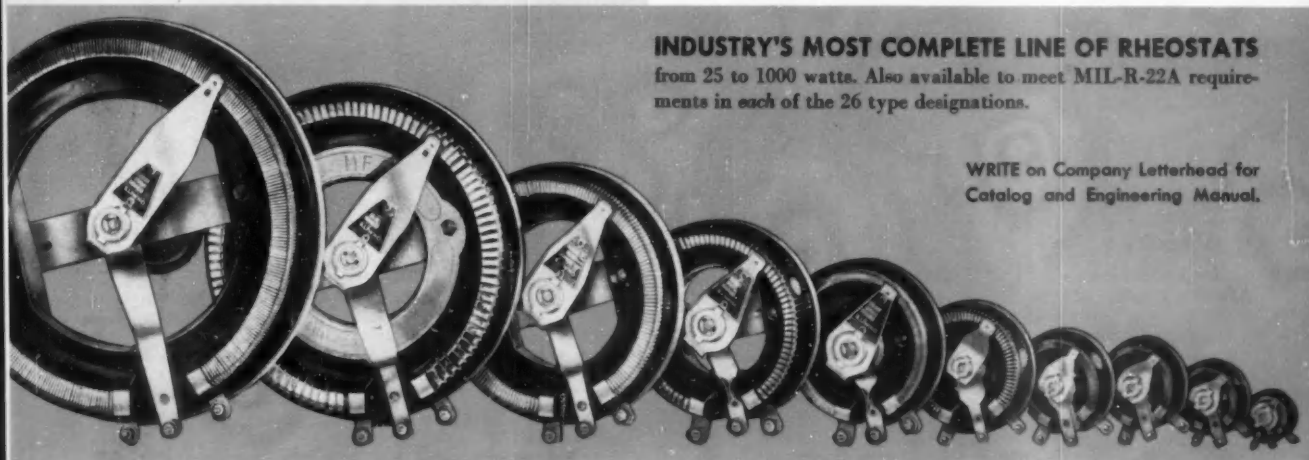
SENSITIVE SWITCH
Opens or closes circuit with minimum movement of control knob shaft. Extremely dependable long life switches.



TOGGLE SWITCH
Is operated with a positive snap by the rheostat arm at either end position. Used for heavy-duty applications.



WITH OFF POSITION FEATURES
Opens circuit at high or low resistance position with *snap-action* (illus.); opens circuit at high resistance position with *dead lug* off position; or has *dead section* off position.



INDUSTRY'S MOST COMPLETE LINE OF RHEOSTATS
from 25 to 1000 watts. Also available to meet MIL-R-22A requirements in each of the 26 type designations.

WRITE on Company Letterhead for Catalog and Engineering Manual.

RHEOSTATS • RESISTORS • RELAYS
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OHMITE MANUFACTURING COMPANY, 3674 Howard Street, Skokie, Illinois



FIRST CHOICE

. . . for high-quality data recording

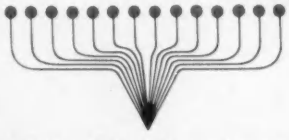
Consolidated's 5-119 Recording Oscillograph was developed to fill user-specified requirements for an exceedingly reliable instrument with great data capacity. The most advanced instrument of its type, the versatile 5-119 provides excellent records in mobile and flight testing applications where severe shock, vibration, and temperatures are commonplace. Throughout industry, it serves as the foundation of successful design-engineering-performance programs.

CEC RECORDING OSCILLOGRAPH

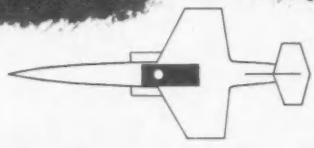
USER-PROVED ADVANTAGES INCLUDE:

extreme clarity of both timing lines and traces at all recording speeds
up to 50 independent channels
wide record speed range
wide frequency range
adjustable scanning speed
automatic record numbering
automatic record-length control
record footage indicator
temperature-controlled galvanometer block
positive gear drive system
built-in shockmount base
quick-change magazines
two independent recording banks
reserve recording lamps
centralized, single-surface controls
automatic warning and safety systems
choice of a-c or d-c models

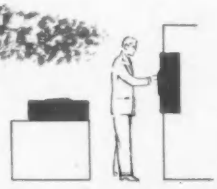
For complete specifications, please contact your nearby CEC field office, or write for Bulletin CEC 1536B-X11.



FLASH TIMING SYSTEM permits absolute timing with external timing pulses. CEC's new Flash Timing System synchronizes timing lines of from 2 to 100 remotely located oscillographs, permits quicker, more accurate interpretation of recorded data.



NEW EXPLOSION-PROOF DESIGN meets safety requirements of military aircraft specifications for test instruments in hazardous locations. This optional modification (5-119P7-50-MB) is available for 400 cycle, 200 volt, 3-phase operation. See Bulletin mentioned above.



OPTIONAL RACKMOUNT is ideal for permanent instrumentation, provides vertical mounting and effective shock isolation for the 5-119 in mobile applications. Even when tilted for adjustments or magazine loading, the 5-119 extends only 13" from front of rack.

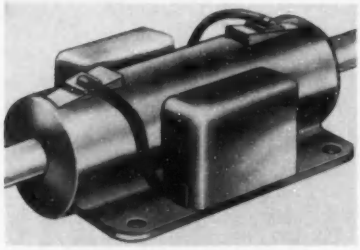
Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

NATIONWIDE COMPANY-OWNED SALES & SERVICE OFFICES

servomotor directly coupled to a drag-cup induction generator. Made of nonmagnetic stainless steel and equipped with a precision gearhead for lower backlash, it will operate in ambient temperatures up to 150 deg C. Applications include instrumentation, fire control, autopilots, missiles, and computers.–Eastern Air Devices, Inc., Dover, N. H.

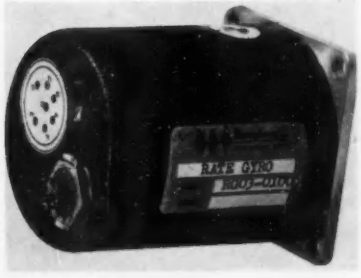
Circle No. 34 on reply card



ULTRASONIC FLOWMETER

Pictured is a straight-through flowmeter that achieves accurate flow rate measurements by the modification of an ultrasonic beam. Features are especially adapted to the measurement of fluids such as kerosene, liquid oxygen, water, and similar low-viscosity liquids. The unit will handle flow rates in the range of 1,000 to 4,000 gpm.–Gulton Industries, Inc., Metuchen, N. J.

Circle No. 35 on reply card



NEW RATE GYRO

This new rate gyro, light, compact, and rugged, is designed for missile applications where severe shock and vibration are encountered. The maker's exclusive wheel and gimbal system eliminates pivots, bearings, or loose springs. This permits use of a standard miniature motor and avoids loading of the gimbal with static mass of the motor. High natural frequency, potentiometer pickoffs, pressure-sealed cases, and trouble-free floating piston dry-air dampers are some standard features of this model.–Humphrey Inc., San Diego, Calif.

Circle No. 36 on reply card

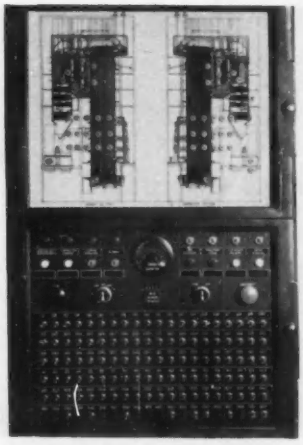
INFORMATION DISPLAY INSTRUMENTS



RADIATION MONITOR

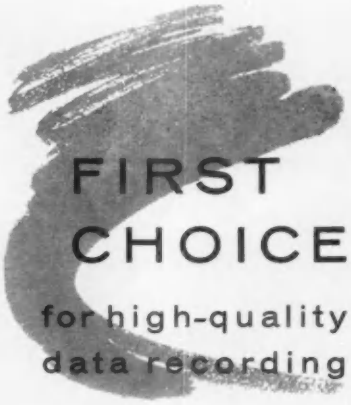
Known as the Nucliguard, this new monitoring unit detects changes in the radio-activity level of an area. Incorporating a recently developed three-cycle logarithmic-count rate meter, the device is available with either a beta-gamma sensitive GM probe, or a gamma-sensitive scintillation probe. Any desired warning level may be preset in the instrument. When this level is exceeded, an alarm operates to warn personnel in the area. Plugs into any 110-volt outlet, weighs about 15 lb.–Nuclear Measurements Corp., Indianapolis, Ind.

Circle No. 37 on reply card



SEQUENCE CONTROL

Shown is the larger of two new selective-sequence controllers for actuating as many as 120 electrically driven, retractable soot blowers and wall de-



CEC's Recording Oscillographs deliver unexcelled accuracy for exacting users throughout the world. There's a quality oscillograph for *your* specific requirement.



5-114 is available in either 18- or 26-trace capacity models with preferred quality features. Described in Bulletin CEC 1500C-X14.



5-116 features 14-trace capacity, a-c or d-c. Economical and highly versatile. Please write for Bulletin CEC 1521A-X10.



5-117 records 6 separate phenomena on 70-mm paper. Precision throughout, small, low-cost. Bulletin CEC 1533B-X11.



5-118 is designed for applications demanding extremely small size and light weight. Please write for Bulletin CEC 1531-X4.

Consolidated Electrodynamics

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41,000,000 feet of VECTOR Cables are now serving the electronics industry!



For more than 10 years, Vector has been manufacturing special-purpose multi-conductor cables for industrial applications. These custom products range from only a few feet in length to more than a mile, and have up to 130 concentrically laid conductors.

Sheathed in continuously extruded rubber or vinyl jackets, thousands of these cables are serving industry under the most severe conditions imaginable, from temperatures far below zero to the heat of tropical jungles. In many of these applications, the cables are required to withstand constant flexing and handling and even towing stresses.

Whether you're designing a complex rocket-firing fixture or connecting portable installations, just send Vector's Engineering Department an outline of your project. We'll work out your multi-conductor interconnection problems with a complete cable installation guaranteed to meet your requirements.

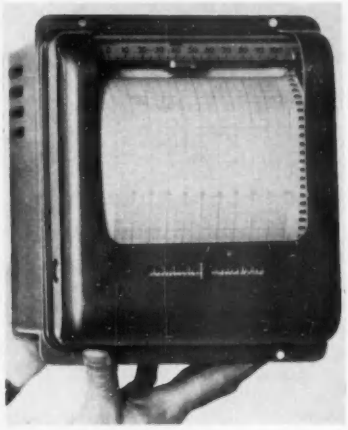
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Western Representative: C. B. Rush and Associates
McKinley Building, 3757 Wilshire Blvd.
Los Angeles 5, California

NEW PRODUCTS

slaggers. Units are complete with indicating lights, master switch, selector switch, malfunction interlocks, annunciators, and means for continuous timed blowing programs of 6, 8, 12, or 24 hours. Blowing sequence is arranged and varied by means of a jack board divided into two panels, one for the blowers and the other for sequence selection. Plug-in control and interlock relays simplify testing and replacement.—Copes-Vulcan Div., Blaw-Knox Co., Erie, Pa.

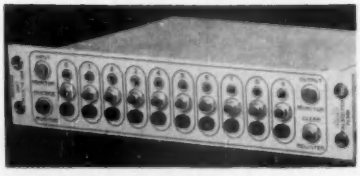
Circle No. 38 on reply card



NEW RECORDER

A new self-balancing strip chart recorder, suitable for panel and relay rack-mounting or portable use, features a unitized measuring circuit. Rectilinear strip chart is 5 in. wide. Single, dual, and quadruple chart-speed models are available. Unit weighs 15 lb and measures 8⅝ in. wide by 10⅜ in. high by 7¾ in. deep. —Varian Associates, Palo Alto, Calif.

Circle No. 39 on reply card



SHIFT REGISTERS

A new line of transistorized indicating shift registers features pushbutton programming, information indication, and number-of-bits selection. Its versatility makes it applicable to operations involving serial to parallel, and

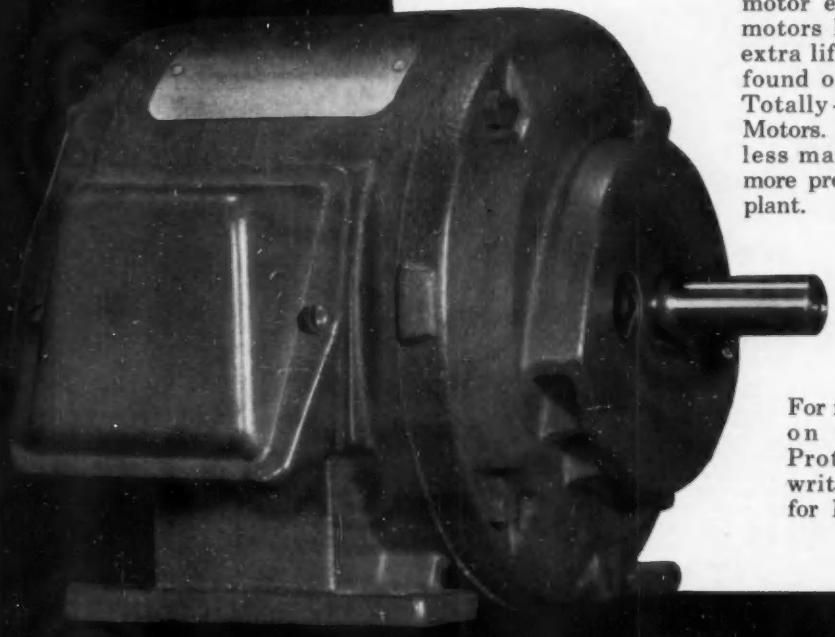
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TOTALLY-PROTECTED MOTOR

When we speak of Totally-Protected, we mean superior frame design with rigidity for heavy load conditions. We mean Metermatic bearing lubrication, acid and oil-proof insulation system, and motor leads, labeled and sealed in neoprene.

Totally-Protected means all this and more, but most of all it means a new concept of motor design and construction.

This Totally-Protected concept brings you a new motor efficiency. These motors have a built-in extra life—an extra life found only in Reliance Totally-Protected A-c. Motors. You profit from less maintenance and more production in your plant.



For more information on this Totally-Protected concept, write to Dept. 523A for Bulletin B-2401.

(B-1543)

RELIANCE R ELECTRIC

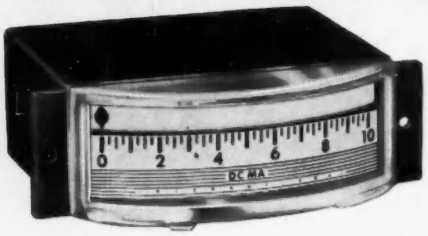
AND ENGINEERING COMPANY

CLEVELAND 17, OHIO • CANADIAN DIVISION: WELLAND, ONT.

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SIDE INDICATOR PANEL METERS



MODEL 1145

APPROX. ½ ACTUAL SIZE

- TWO SIZES–Models 1145 and 1120
- Horizontal or Vertical Mounting
- Maximum Accuracy and Readability

Save space on crowded, complex electronic controls and other panels without sacrificing accuracy or readability. These instruments provide same scale length as comparable conventional round meters, but occupy only 1/3 the panel area and are ideal for the redesigning and streamlining of panels. The wide range of standard and special ranges includes Expanded Scale Voltmeters, VU and DB meters.

Our Complete Line of Miniature Components Will Be On Display at the

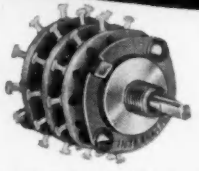
I.R.E. Show, NEW YORK, Mar. 18, 19, 20, 21

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international ii instruments

Since 1947, GROWING BIGGER making things smaller



sub-miniature

ROTARY SWITCH

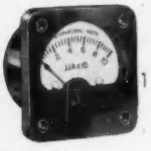
- Up to 12 Positions per Deck
- Up to 3 Decks

A low-contact-resistance switch ideal for use in all electronic and test equipment applications where small size plus peak performance are essential. Available with 1, 2, 3 or 4 poles on each deck and with either shorting or non-shorting contacts; or rotor contacts shorting out any variations from 2 to 11 positions. Features include: specially impregnated glass melamine wafer, solder type lugs, and positive indexing.

1" ROUND and 1½" ROUND and SQUARE METERS



1" Meters have full 90° scale arc, scale length .760" 1½" meters to Military Specifications MIL-M-3823 and MIL-M-10304 (Sig. C.) Also self-contained VU and DB meters, and illuminated models with lamp housing attached.



WRITE FOR ENGINEERING DATA SHEETS COMPLETELY DESCRIBING THESE MINIATURE COMPONENTS

1½" Ruggedized Meters • 1" and 1½" Panel Meters • 1½" VU, DB and Illuminated Meters • Miniature Multitesters • Side Indicators

P.O. BOX 2954, NEW HAVEN 15, CONNECTICUT

NEW PRODUCTS

parallel to serial information transfer. Amplified outputs are available to drive relays or tape recording heads. Units are complementary to a complete line of transistorized logic units made by this company.–Navigation Computer Corp., Philadelphia, Pa.

Circle No. 40 on reply card



2-IN-1 RECORDER

Shown is a new two-pen, two-zone recorder claimed to be ideal for comparative measurement. It employs two electronic amplifiers, and two measuring circuits with replaceable range standards. Plug-in construction of the amplifiers simplifies servicing. Alarm switches are available for each zone and can be set in a matter of seconds. Chart speeds from 1 in. per hour to 1 in. per min are available. Interchangeable slidewires are totally enclosed.–Weston Electrical Instrument Corp., Newark, N. J.

Circle No. 41 on reply card

POWER SUPPLIES

LAB POWER SUPPLIES

Designed for mounting in a standard 19-in. relay rack, two new heavy-duty power supplies incorporate protection against overload and internal failure. Both are electronically controlled and substantially free from noise and hum signal. Input of each unit is 105 to 125 volts, 50 to 400 cps. Dc regulation is 0.15 percent or 0.3 volt,



A major step forward has been achieved by uniting Fairchild precision potentiometers with dynamically balanced and sensitive pressure-sensing elements. The result is a line of superior pressure transducers with potentiometer outputs and featuring all the characteristics of precision, reliability and quality that are identified with Fairchild potentiometers. A specially trained staff of engineers is at your service to consider problems of transducer design and manufacture to meet your specific requirements.



MINIATURE PRESSURE TRANSDUCERS

Featuring Fairchild accuracy and reliability

The TP-200 illustrated is a new and smaller addition to the line of Fairchild Transducers. These components are now available in a wider range of resistances in either linear or functional, single or dual potentiometer output elements. Measuring only approximately 2" by 2", the TP-200 features a single pressure sensitive diaphragm element which actuates one or two precision potentiometers through dynamically-balanced, stable mechanical linkage. It features unitized construction for easy assembly, field calibration and repair. Variations of size, conformation, and pressure ranges for measurement of differential, absolute, or gauge pressures are available. For complete information write Fairchild Controls Corp., Components Division, Dept. 140-77C2.

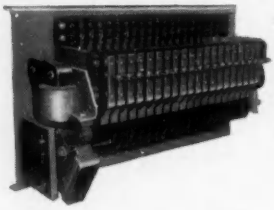
EAST COAST
225 Park Avenue
Hicksville, L. I., N. Y.

WEST COAST
6111 E. Washington Blvd.
Los Angeles, Calif.

FAIRCHILD
PRECISION POTENTIOMETERS and COMPONENTS

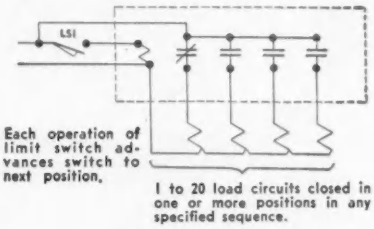
NEW EAGLE STEP SWITCH SIMPLIFIES CIRCUIT SEQUENCING

. . . for machine tools, presses, conveyors, processes

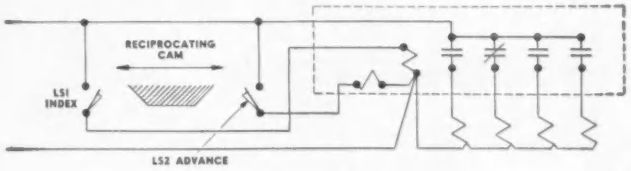


These 3 basic ideas are yours for simplified interlocking or sequencing of multiple load circuits. Any and all three will eliminate many other electrical components, and cut your initial cost.

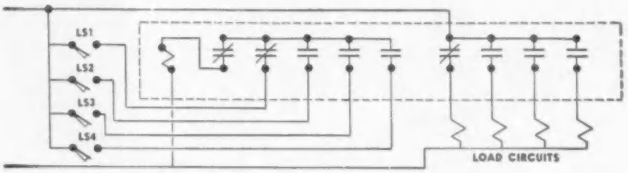
Operating load circuits in sequence: A limit switch on a machine or indexing device closes and opens upon each operation to advance the Eagle step switch. Or a timer may be used to operate each load circuit for a predetermined time.



Interlock sequence: *Two limit switches* are operated alternately. This provides a safety feature. It insures that the movement of the machine has been completed before the Eagle step switch advances.



Interlock sequence with several limit switches: Each limit switch advances the Eagle step switch one position. Switches must operate in sequence or the step switch won't advance.



Send for new Eagle Bulletin 850. Simply write to Eagle Signal Corporation, Industrial Timers Division, Moline, Illinois, Dept. CE-357.

(whichever is greater) against line, and 0.25 percent or 0.5 volt (whichever is greater) against load. Internal impedance is less than 6 ohms and ripple below 3 mv rms. Output of the Model PS-L225 is 125-325 volts, 0-200 ma dc, or 6.3 volts, 10 amp ac; that of the Model PS-L425 is 325-525 vdc.—Reflectone Corp., Stamford, Conn.

Circle No. 42 on reply card



NEW GEAR MOTOR

A new 400-cycle hysteresis synchronous gear motor designed for airborne strip chart recorders and other applications is now available. The new motor, physically interchangeable with the maker's 60-cycle motors, is designed for 115 volts, 400 cps, 100 rpm, and 7.5 oz-in. continuous duty rating. The motor will soon be available with other speeds, both synchronous and induction, and adjusted ratings.—Holtzer-Cabot Div., National Pneumatic Co., Boston, Mass.

Circle No. 43 on reply card

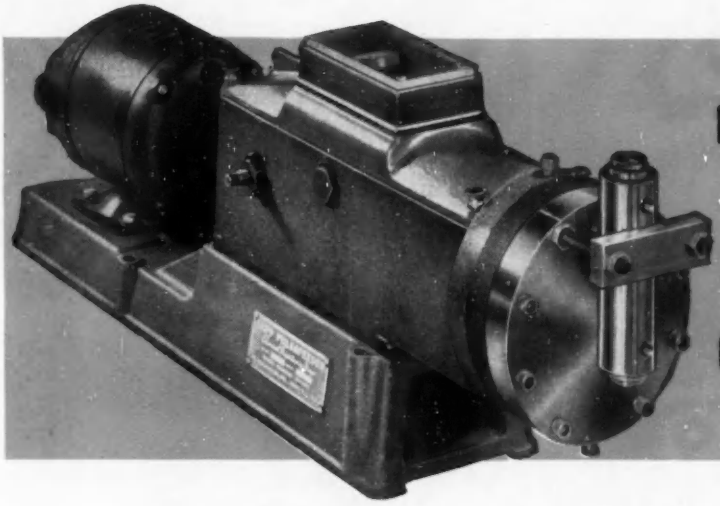


COMPUTER POWER SUPPLY

Developed for computer applications, this dc power supply features a steady-state regulation accuracy of plus or minus 0.01 percent. Peak-to-peak

CONTROLLED-VOLUME PUMPING with

NO STUFFING BOX PROBLEMS!



Lapp
PULSAFEEDER
CONTROLLED-VOLUME
CHEMICAL PUMP

The Pulsafeeder, in combining the good features of both piston and diaphragm pumps, provides an unusually dependable means of precision pumping. There is no stuffing box, hence the usual problems of maintenance and repacking associated with plunger-type metering pumps do not exist. The product being pumped is isolated from the pump's working parts by a hydraulically balanced diaphragm and is kept safe from contamination and leakage to atmosphere.



SUCTION STROKE



DISCHARGE STROKE

Positive displacement is achieved by a piston reciprocating within an accurately sized cylinder at an established stroke length, displacing an exact volume of hydraulic oil. By means of this oil, the piston moves the diaphragm alternately backward and forward. The displacement of this diaphragm travel takes in the liquid on the suction stroke of the piston and discharges a like amount of liquid on the discharge stroke of the piston.

WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 705 Wilson Street, Le Roy, N. Y.*

Lapp

"BANTAM"



500 SERIES

Miniature Throttling

Diaphragm Control Valves

Because of the growing need for compactly designed, lightweight valves with the same ruggedness of construction and high quality found in standard dimensioned control valves, this new line of "Bantams" is offered.

The type 501 valve shown has ¼" N.P.T. connections, and for service up to 1000 psi at 350°F. will provide throttling control with low hysteresis and instantaneous response over a 3 to 15 psi instrument air range. It has five interchangeable sizes of linear, equal percentage, or quick opening trim. CV = 0.63 to 0.00025 trim sizes.

Types 526 and 530 valves are available in sizes from 1" to ¼" screwed, flanged, and weld ends, for service up to 1500 psi in A.S.A. Ratings. All materials and construction are consistent with usual control valve specifications.

Reversible integral seat and replaceable seat bodies are available as well as the usual control valve extras.

For a full description of the Bantam 500 series, drop us a line. We will be glad to put you in touch with our representative in your area.

George W. DAHL Company

BRISTOL, RHODE ISLAND

NEW PRODUCTS

ripple is below 50 mv, and dc output is 200 volts, plus or minus 10 percent at 3 amp. The unit also has an extremely low dynamic impedance, using an ultra-fast magnetic amplifier with instantaneous electronic control. No saturating-type ac regulators or large-energy storage capacitor banks are used. Overall dimensions are 19½ by 12¾ by 15 in.—Perkin Engineering Corp., El Segundo, Calif.

Circle No. 44 on reply card



DC REFERENCE

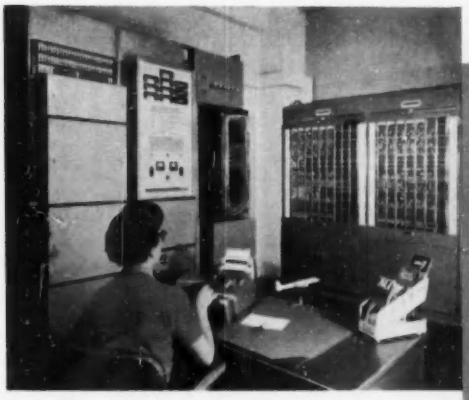
Simplicity of design and encapsulated construction provide maximum stability and service life in this new constant-reference voltage supply. Its ability to convert ac into a highly stable dc voltage makes it ideal for such applications as adjustable-speed motor drives and dc servo systems. —Servo-Tek Products Co., Inc., Hawthorne, N. J.

Circle No. 45 on reply card



NUCLEAR POWER

A family of small, light Nuclear Power Packs, with a shelf and use life of over 25 years, has recently been developed. The units are capable of



AMP'S PATCHCORD PROGRAMMING SYSTEM

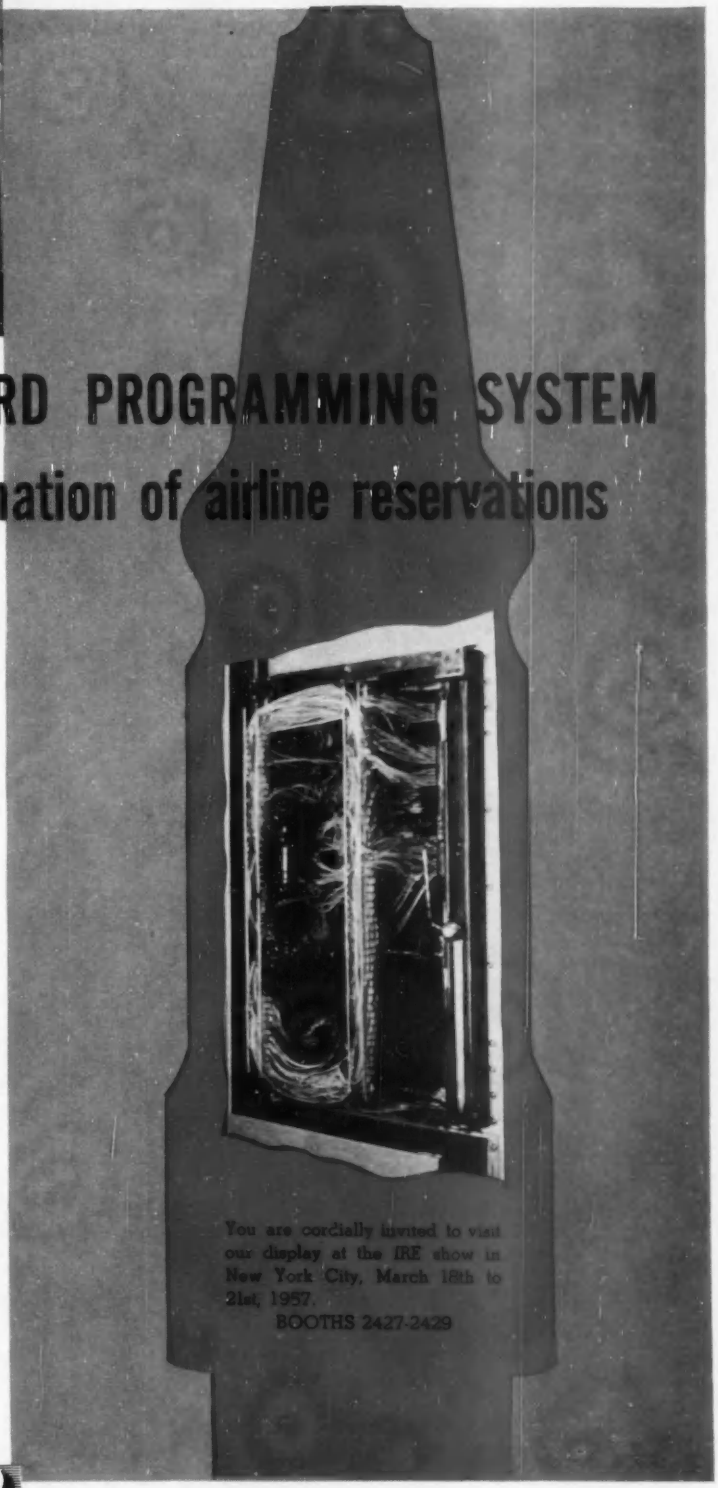
Speeds confirmation of airline reservations

A wide variety of AMP Taper Technique product provides long-life assurance of perfect electrical terminations and is a contributing factor in keeping electronic equipment compact. The AMP Patchcord Programming System offers a multiformity of internal wiring arrangements and connections and permits circuit versatility by use of prepatched, removable front boards.

A number of major airlines, including the Long Island City facilities of Pan American Airlines (shown above), have installed electronic equipment manufactured by Teleregister Corporation, Stamford, Connecticut to eliminate delay and uncertainty in air travel reservations procedure. AMP Taper Technique and AMP Patchcord Programming Systems are prominent in the design of this equipment.

AMP Taper Technique and AMP Patchcord Programming Systems have been utilized for years to solve problems inherent in the design of computers, business machines, and automatic control equipment.

Complete information is available on request.

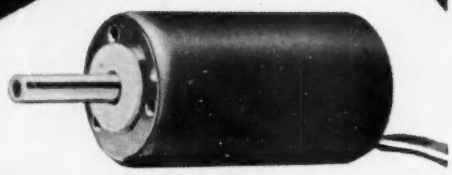


You are cordially invited to visit our display at the IRE show in New York City, March 18th to 21st, 1957.
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HEART of your miniaturization program



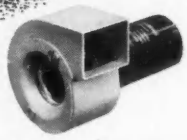
the EAD 1" MOTOR

Here is EAD's outstanding contribution to the miniaturization program... a one-inch diameter, 400 cycle precision motor, engineered for long life and high efficiency. Where minimum size and weight are essential, use this versatile unit. Modifications include high ambient and high altitude versions as well as low voltage designs.

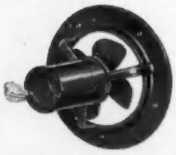
VISIT BOOTH 3915
I.R.E. SHOW



MINIATURE TUBE AXIAL BLOWERS
For efficient cooling and air change in small electronic equipment. Driven by EAD's 1" dia. motor. No brushes, no arcing, no interference.



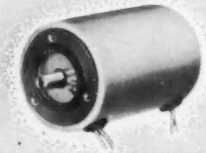
SUBMINIATURE CENTRIFUGAL BLOWERS
For spot cooling. Moves 9 CFM at 1.35 S.P. Powered by EAD's 1" dia. motor.



MINIATURE RING MOUNTED FANS
For peak performance, compactness, dependability. Blade dia. small as 2" — air del. greater than many heavier blowers. Uses EAD's 1" dia. motor.



MINIATURE GEAR MOTORS
Servo, synchronous or induction units, primarily for 400 cycle and var. freq. operation. Gear ratios up to 10,000 to 1. Basic types use EAD's 1" dia. motor.



MINIATURE SINE WAVE ALTERNATORS
For very pure sine wave voltage, high power output. Low distortion, light weight, permanent magnet fields. Frame sizes begin with 1" diameters.

Complete specifications available on request.

EASTERN AIR DEVICES, INC.

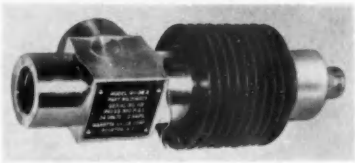
SOLVING SPECIAL PROBLEMS IS ROUTINE AT EAD

375 Central Ave., Dover, New Hampshire

operating over wide ranges of temperature, acceleration, and vibration. The heart of each power pack is a nuclear battery that converts nuclear energy directly into electrical energy. Current ratings range from 5 to 5,000 micro-microamps, and equilibrium voltages are in the order of 10,000 volts.—Patterson Moos Div., Universal Winding Co., Jamaica, N. Y.

Circle No. 46 on reply card

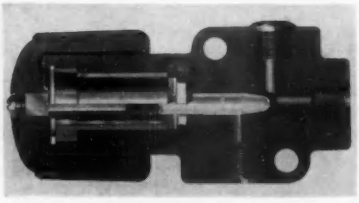
FINAL CONTROL ELEMENTS



HIGH TEMPERATURE

Air temperatures to 1,000 deg F and air pressures to 4,000 psi are easily controlled by this 24-volt dc pneumatic solenoid valve. Flow characteristics are equivalent to those of an elbow fitting of the same size, actuation time is less than 0.05 sec, and internal leakage is said to be negligible. Manufacturer will supply the valve in a range of sizes from ¼ in. to 2 in. Unit can also be made available for liquid oxygen and high-temperature hydraulic applications.—Marotta Valve Corp., Boonton, N. J.

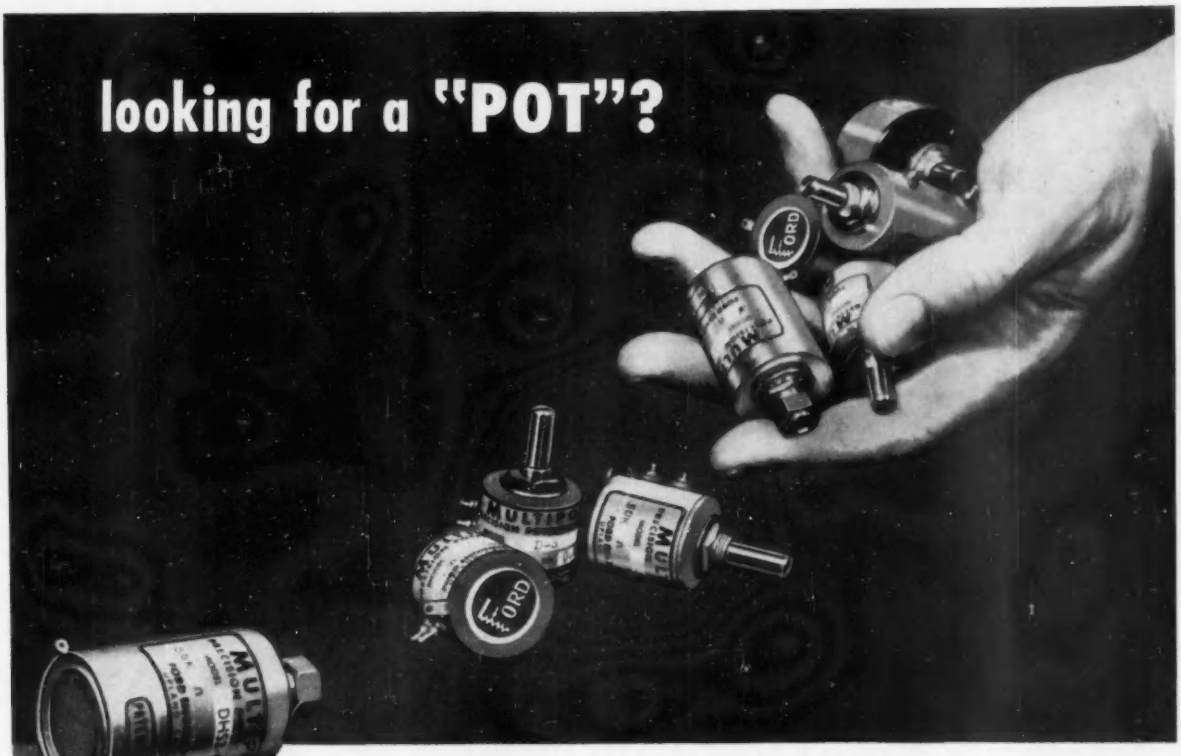
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FOR CORROSION SERVICE

A new bubble-tight needle valve, compatible with standard fittings and piping methods, has been designed to handle corrosion problems caused by internal, external, chemical, electrical, or even natural corrosive ele-

looking for a "POT"?



THREE OF THE MANY "MULTIPOTS" IMMEDIATELY AVAILABLE. (All models available in 1, 3, 5 and 10 turn, and wide range of resistance values.)

FORD "MULTIPOTS" by DAYSTROM PACIFIC CORPORATION

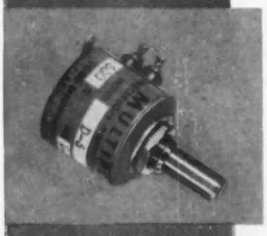
Wire-wound, Precision-built, Multi-turn Potentiometers
WITH:

- HIGH RESOLUTION
- CLOSE LINEARITY
- EXCELLENT PERFORMANCE UNDER EXTREME VIBRATION

The Ford Engineering Company, Inc. "Multipots" compliment the many precision-built, wire-wound, sub-miniature potentiometers already produced by Daystrom Pacific Corporation, so that Daystrom now can fill all of your potentiometer needs with top-quality production model potentiometers.



MODEL "RU" Standard 1 7/16" diameter with 4 watt power, maximum resistance and resolution.



MODEL "D" 1" diameter and minimum length.



MODEL "DH" Sealed and metal clad for operation under adverse humidity and vibration.

ALL FORD "MULTIPOTS" IMMEDIATELY AVAILABLE

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DAYSTROM PACIFIC CORPORATION
A Subsidiary of Daystrom, Inc.

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DAYSTROM POTENTIOMETER

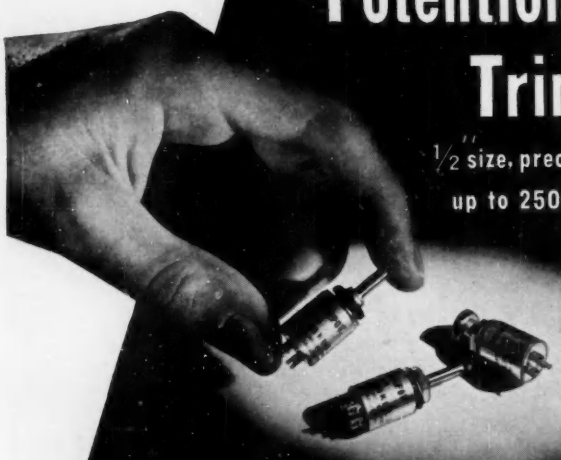
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Remember D for Daystrom, Daystrom for Dependability

ACEPOT*
ACETRIM*

Sub-Miniature Potentiometers and Trimmers

½" size, precision wire-wound, up to 250K, ±.3% linearity



setting *new* standards for *dependability* in sub-miniaturization

Let the facts speak for themselves! ACE Sub-Miniature Precision Wire-Wound Potentiometers and Potentiometer Trimmers are the result of 4 years development and over a year of successful use by leading electronic equipment manufacturers. Users have conclusively proved that ACEPOTS and ACE-TRIMS meet requirements for space and weight saving compactness, while at the same time meeting MIL specs' most stringent qualifications for performance and *dependability*. Why invite trouble with untested components when you can *protect your reputation with* ACEPOT and ACETRIM . . . the subminiature potentiometers and trimmers proved in actual use.

Condensed Engineering Data

	ACEPOT (potentiometer)	ACETRIM (trimmer)
Resistance Range	200 Ω to 250K ± 2%	10 Ω to 150K ± 3%
Linearity	±3%	±3%
Resolution	extremely high	excellent
Ambient Temperature	−55° C to 125° C*	−55° C to 125° C
Torque	low or high	low or high

The above specifications are standard — other values on special order.

Available in threaded bushing, servo, flush tapped hole or flange mounting, and ganged units. All units sealed, moistureproofed, and anti-fungus treated. Meet applicable portions of JAN specs and MIL-E-5272A standards.

***New X-500 ACEPOT operates to a *new* high of 150° C.**

Expedited delivery on prototypes; prompt servicing of production orders. Send for Fact File and application data sheets.

*trademarks applied for

ACEPOT*
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ACE ELECTRONICS ASSOCIATES

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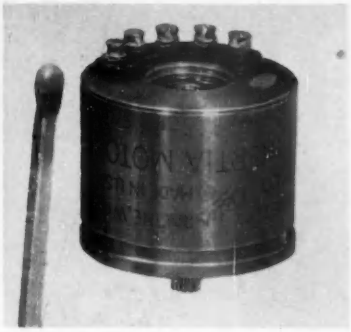
"See the newest and latest at Booth 1807, the IRE Show"

NEW PRODUCTS

ments. Made from Teflon, Polyvinyl Chloride, "Kel-F", and 18-8 stainless steel, the units are said to permit precision control and recording of settings. They are available in ⅛ in. and ¼ in. female pipe sizes and ⅛ in., ¼ in., and ⅜ in. OD male tube connections.–Chemtrol Corp., Compton, Calif.

Circ'e No. 48 on reply card

COMPONENT PARTS



SIZE-10 SERVO

Designed specifically for use with a transistorized amplifier, this new size-10 servo is said to be less prone to single phasing. Precision electrical characteristics include: 115-volt fixed phase, 36-volt control phase with 3 watts per phase stalled, 6,500 rpm at no load, and 0.26 in.-oz at stall minimum. Operating temperature range is minus 65 to plus 85 deg C.–John Oster Mfg. Co., Avionic Div., Racine, Wis.

Circle No. 49 on reply card



PRECISION GEARHEADS

A special flush collar mounting on this new precision gearhead assures

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(100) BORON CARBON "PRECISTORS". International Resistance Co. Catalog Data Bulletin B-6b, 4 pp. Presents comprehensive data on construction, characteristics, applications, types, identification, etc., of precision resistors. Detailed charts and graphs show temperature coefficient and frequency characteristics.

(101) AUTOMATIC CONTROLS. The Mercoid Corp. 1957 Catalog, No. 857, 56 pp. Lists controls for single-stage, two-stage, and differential pressure, single-stage and two-stage temperature, liquid level, and mechanical movement. Also shown are relays and a complete line of mercury switches. Fully indexed by both type and number.

(102) AUTOMATIC LUBRICATOR. J. N. Fauver Co., Inc. Catalog No. CL-956, 8 pp. Describes in detail two new automatic conveyor lubricators covering purpose, design, operation, and advantages. Exploded isometrics of both a solid injection and spray type are included for identification of part numbers.

(103) MINIATURE BATTERIES. Nickel Cadmium Battery Corp. Bulletin No. 501, 8 pp. Demonstrates the usefulness of miniature nickel cadmium storage batteries in electronic, aircraft, and communications equipment. Curves illustrate typical discharge characteristics of these high-rate sintered plate cells, and the relatively low voltage drop as discharge current increases.

(104) VARIABLE PITCH DRIVES. Browning Mfg. Co. Catalog V-183-A, 12 pp. Describes several new types of sheaves for variable speed drives, including a single groove, wide range, variable pitch and companion model, and a single- or double-groove locking ring type. Also includes specifications, engineering data, and tables of practical stock-drive combinations.

(105) PUSHBUTTONS. Furnas Electric Co. Catalog 5606A, 32 pp. Covers pushbuttons, selector switches, and pilot lights used for remote pilot control of magnetic controllers and similar devices. The line includes standard-duty, heavy-duty and oil-tight models. Also contains three pages of schematic diagrams.

(106) "AN" FASTENERS. Allmetal Screw Products Co., Inc. Catalog, 12 pp. Describes government specification aircraft bolts, slotted and recessed machine screws, flat and round rivets, washers, and other stainless steel AN fasteners. Illustrations, stock sizes, and principle dimensions given.

(107) TRANSFORMERS & REACTORS. Southwestern Industrial Electronics Co. Catalog 105, 8 pp. Covers a full line of miniature, low-frequency transformers and reactors. Includes input, output, interstage, and AVC output transformers, gives design, application, and mounting information concerning these components.

(108) AIRCRAFT SWITCHES. Minneapolis-Honeywell Regulator Co. Catalog 78, 32 pp. Entitled "Basic Switches for Airborne Equipment", this catalog covers a complete line of phenolic-encased aircraft switches as well as small, metal-covered, hermetically sealed switches and high-temperature switches. Gives photographs, dimensional drawings, electrical data, and operating characteristics.

(109) AUTOTRANSFORMERS. General Radio Co. Bulletin "O", 24 pp. New catalog describes General Radio's complete line of Variac® adjustable autotransformers. Dimensions, drawings, and photographs included for all models. Specifications and prices tabulated for single units and ganged assemblies.

(110) MEASURES MOISTURE. Henry Francis Parks Laboratory. Form No. 1231.

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Describes the model 910 MOISTUROMETER, stating principle of operation and applications. Special electrodes, at extra cost, and other special adaptations also discussed.

(111) HIGH ENERGY PM. Indiana Steel Products Co. Bulletin No. 16, 2 pp. Shows typical characteristics of a new high-energy ceramic permanent magnet called INDOX V. Lists design advantages and limitations, applications, and available sizes.

(112) ELECTRICAL CONTACTS. Gibson Electric Co. Short Form Catalog, 4 pp. Describes materials, properties, forms, and uses of the Gibson line of electrical contacts. Dimensioned drawings are included along with an outline showing the best contacts for a number of applications.

(113) FOR MACHINE CONTROL. R. B. Denison Mfg. Co. Bulletin 956, 8 pp. Contains a cutaway illustration of a heavy-duty limit switch, showing how it conforms to a number of NEMA specifications. Nine models and 22 contact arrangements covered. Describes the housing, gives wiring diagrams, ampere ratings, operating data, and electrical characteristics.

(114) PROCESS REFRACTOMETER. Phoenix Precision Instrument Co. Bulletin R-1000, 8 pp. Contains two full pages of general information on the refractive index method of analysis and differential refractometers. Discusses monochromatic light, photomultiplier tubes, the optical servo system, and calibration. Photographs accompany descriptions of several models.

(115) DATA HANDLING SYSTEM. Berkeley Div. of Beckman Instruments, Inc. Technical Bulletin, 2 pp. Contains some useful information on a new data-handling system that offers high-speed storage on magnetic tape, playback into an electric typewriter or serial IBM summary punch, and continuous time readout.

(116) WEAPONS SYSTEMS. Servo Corp. of America. Catalog IR-9902, 6 pp. For security reasons, this bulletin contains only a sketchy treatment of this company's contributions in infrared weapons systems. Applications covered include reconnaissance, guided missiles, bombing, fire control, and countermeasure systems.

(117) LAB POTENTIOMETER. Leeds & Northrup Co. Data Sheet E-51(6), 6 pp. Lists complete specifications of a new Type K-3 Universal (Guarded) Potentiometer, and gives typical laboratory applications.

(118) TAPE RECORDER. Ampex Corp. Booklet, 20 pp. Attractive booklet describes the capabilities and characteristics of the Ampex FR100 tape recorder. Numerous illustrations show transports, heads, and modular electronic assemblies.

(119) INDUSTRIAL REGULATORS. Fisher Governor Co. Bulletin C-655, 4 pp. Describes the Series 655 self operated regulators which are designed for a wide variety of industrial applications.

(120) RECORDER ACCESSORY. Houston Technical Laboratories. Bulletin No. R-501 VM, 2 pp. Tells how an additional application of the Recti/riter recorder is made possible by a new attachment. By means of a Line Voltage Monitor, the instrument becomes an expanded scale graphic voltmeter for recording line-voltage variations.

(121) GAS LIQUEFIER. North American Philips Co., Inc. Bulletin RC-163-5MA, 6 pp. Illustrated with photos and drawings, this bulletin shows the operating cycle and construction of a new gas liquefier. Technical details cover speed, efficiency, yield, motor characteristics, cooling water consumption, weight, and size.

(122) DEHYDRATORS. Robbins Aviation. Bulletin 1157, 8 pp. Describes various types of dehydration systems for a number of applications. Gives dimensions and working pressures for mechanical filters, purifier chambers, and reactivating dehydrators. Interchangeable filter elements and oil-vapor cartridges are included.

(123) SMOKE INDICATORS. Brook Engineering Co., Inc. Bulletin No. 30, 4 pp. Gives some pertinent data on a new, improved smoke indicator and several indicator-recorders. Also describes a standard and a heavy-duty photoelectric scanner and light source.

(124) MICRO-MICROAMMETERS. Leeds & Northrup Co. Data Sheet E-03(1), 2 pp. Two types of micro-microammeters for nuclear reactor control systems described. The sheet also lists complete engineering features and ordering information.

(125) TUBE FITTINGS. Parker Appliance Co. Catalog 4360, 12 pp. Shows a complete line of adapter fittings, including pipe fittings, straight-thread plugs, locknuts, and O-rings. Photographs, dimensioned drawings, and tables contain all the information required by the systems designer. Reference chart covers standard O-ring compounds.

(126) COLOR CODE D GASKETS. General Gasket Inc. Illustrated Folder, 4 pp. Describes a new plastic gasket material which is color-coded according to its thickness. Gaskets, shims, spacers, and washers can be made from this material. Tables list standard items available from stock.

(127) MINIATURE TERMINALS. International Resistance Co. Catalog Data Bulletin LT-1, 4 pp. Contains comprehensive data on construction, applications, specifications, properties, designations, dimensions, and installation of Type LT hermetic seal terminals. Detailed charts and diagrams cover each body size.

(128) CUSTOM DESIGN. Nelson Instrument Co. Brochure, 6 pp. Describes this company's facilities for electronic research, development, and production. Illustrates

a wide range of custom-built controls, research apparatus, industrial automation, medical instrumentation, and other electronic equipment.

(129) PNEUMATIC TRANSMISSION. Simplex Valve & Meter Co. Bulletin 750, 8 pp. Gives a complete description of the Simplex Laminair, a pneumatic transmission system that provides a highly sensitive and accurate type of instrumentation. Advantages and suggested specs covered.

(130) POWER SUPPLIES. Opad Electric Co. Catalog, 16 pp. Covers a complete line of standard low-voltage rectifier power supply equipment. Also a "Power Equipment Questionnaire" for requesting further information and quotations on special and custom-built power supplies.

(131) NEW FLOWMETER. Brooks Rotameter Co. Bulletin No. 400, 2 pp. Contains some informative data on the VAF-Brooks Type A2 positive displacement flowmeter. Explains the principle of operation, and lists some of the more important design features.

(132) COATED RESISTORS. Continental Carbon Div. of Wirt Co. Bulletin 307, 2 pp. Lists characteristics and specifications of ceramic encased carbon and coated carbon resistors. Physical dimensions and electrical ratings are tabulated for easy reference. Derating and temperature coefficient curves included.

(133) TEMPERATURE CONTROLS. Burling Instrument Co. Bulletin 106, 2 pp. Includes a description of Burling's Model L-1S temperature control, illustrates its differential expansion operation, and gives specifications, temperature ranges, tube sizes, and accuracy limits. Also discusses modifications and mounting dimensions.

(134) MINIATURE EQUIPMENT. Southwestern Industries, Inc. Brochure No. SW-1, 4 pp. Describes and illustrates Southwestern's miniaturized gear boxes, miniaturized vibration-resistant pressure switches, and lightweight, compact screw-jack actuators. The company's equipment, research and development facilities, and customer services also discussed.

(135) INDUSTRIAL COILS. Stonite Coil Corp. Bulletin No. S-20, 8 pp. Informative brochure explains the need for superior design, workmanship, materials, and finish in the construction of their vacuum-impregnated coils. Photographs of the Stonite facilities show the care with which these custom industrial coils are made.

(136 NEW GAGE MOVEMENT. Norden-Ketay Corp. Bulletin 403-A, 4 pp. Lists the characteristics and specifications of the manufacturer's new "Bandrive" pressure gages. Describes the new gage movement, and cites several advantages over gear-type movements.

(137) BAGGER AND SCALE. Richardson Scale Co. Bulletin No. 0356, 6 pp. Describes and illustrates Richardson's E-52 gross bagger that weighs and bags adhesive and nonadhesive materials in 25-to-100-lb bags. Operation and three different types of feed arrangements are discussed in separate sections.

(138) RECIPROCATING PUMPS. Gray Company, Inc. Catalog No. 453, 44 pp. Illustrates a complete line of air-powered reciprocating pumps for a variety of applications.

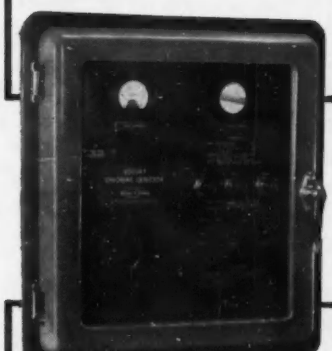


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... For Precise Vacuum Work

Accuracy:	1/300 of full scale
Sensitivity:	1/500 in *all* ranges
Ranges:	0-50mm Hg. 0-100mm Hg.
	0-200mm Hg. 0-410mm Hg.
	0-800mm Hg. 390-800mm Hg.
Dial Sizes:	2¾" or 6" diameter for all ranges

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A-108



HOW TO DETECT 3 PARTS CHLORINE IN A MILLION PARTS AIR

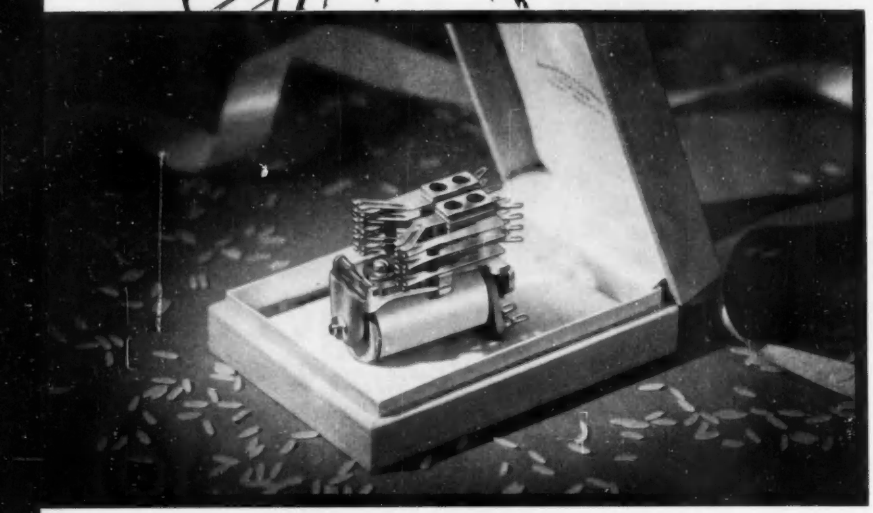
New W&T Solvay Chlorine Detector*
detects as little as 3 p.p.m. chlorine in a continuous air-stream sample. Automatically sets off alarm at higher concentrations.
Write for Publication 50.118

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INCORPORATED
25 MAIN ST., BELLEVILLE 9, N. J.

I-55 *Manufactured under patent license from Solvay Process Div., Allied Chemical & Dye Corp.

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COIL CHARACTERISTICS:
Operating Voltage: up to 300 volts D.C.
Resistance: up to 21,000 ohms.
Single or double wound.
Operating Current: 0.002 Amps., minimum
Operating Time: 0.060 Secs., maximum
0.002 Secs., minimum

CONTACT ASSEMBLY:
All forms A thru E.
Single or double pileup
Code #24 Twin Palladium contacts, standard
Other contacts available.

MOUNTING:
Two No. 6-32 Tapped holes, standard

VARIATIONS:
Plug-in mounting and terminals
Printed circuit terminals
Taper tab terminals
Metal enclosures
Hermetically sealed.

your relays propose problems? Long life, compactness, high reliability and close adjustment! Are these all requirements for your electronic control, communication or data handling application? Then, the multi-contact telephone Type 8 relay is for you. To assure performance while retaining precision adjustment, Type 8 is fitted with a heavy duty bronze armature bearing. Standard twin contact springs insure maximum reliability with minimum contact resistance. Versatile, too, this relay is available with many variations in coils, contact assemblies, contact rating, adjustments, terminal arrangements and mountings — each combination for a specific application. Single or double-wound coils, for almost any voltage or current operation, may be equipped with slugs or sleeves for time delay on pick-up or drop-out.

Whatever your specifications, whatever your application—get in touch with the reliable "man from PHILLIPS." Write, wire or phone the Phillips office nearest you.

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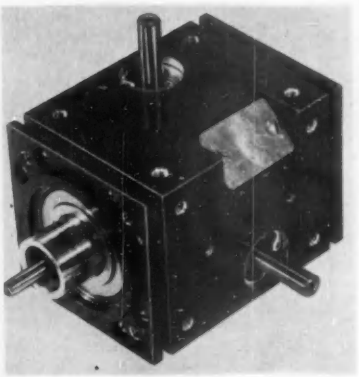
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NEW PRODUCTS

permanently accurate mesh of motor pinion and first gear. This model, G-11, and two others, G-15 and G-18, are available from stock in ratios from 10:1 to more than 4,000:1. —Feedback Controls, Inc., Waltham, Mass.

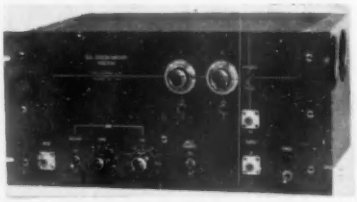
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SPHERE RESOLVER

Pictured here is a new miniaturized, mechanical, Ball Resolver for analog computation applications. Its 0.1248-in. input shaft, driven at 100 rpm, requires less than 5 in.-oz at 25 deg C for an output of 1 to 2 in.-oz at the 0.187 in. sine and cosine output shafts. A 0.500-in. orientation shaft, concentric with the input shaft, establishes the output relation. Unit measures 1½ in. square by 2⅛ in. long and weighs less than ¾ lb.—Vectron, Inc., Waltham, Mass.

Circle No. 51 on reply card

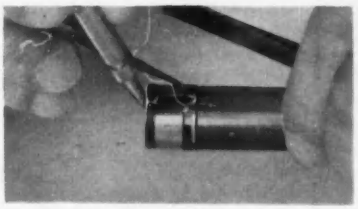


AMPLIFIER-ANALYZER

Designed for scintillation spectroscopy, single-component monitoring, and proportional-counter pulse analysis, this instrument combines a stable nonoverload pulse amplifier with a precision single-channel analyzer, all on one standard-size chassis. The amplifier uses delay-line clipping and long-tailed pair stages with feedback.

Overloads as large as a factor of 100 are easily handled, according to the manufacturer.–Hamner Electronics Co., Inc., Princeton, N. J.

Circle No. 52 on reply card



METER MOTOR

A d'Arsonval torque-motor is now being used in a miniature gyroscope especially designed for fire-control systems. When the gyro is subjected to a rotation, a spin-motor produces a torque proportional to the rate of rotation, causing a fully-floated gimbal to rotate relative to the gyro case. This motion is detected by a position detector, and by means of a feedback amplifier a current is delivered to the torque motor. The torque-motor generates the restraint necessary to balance the precession torque produced by the gyro rotation. The concentric construction of the torque-motor is shown above.–Westinghouse Electric Corp., Baltimore, Md.

Circle No. 53 on reply card

ACCESSORIES & MATERIALS



AIR-GAS TRAP

Shown is a brand-new type of compressed air and gas trap that discharges condensate from compressed air and gas lines by a combination of magnetic, pneumatic, and auto-

$$C/R = \frac{(K_1K_2K_3)(1+j\omega T_1)(1+j\omega T_3)}{j\omega(1+j\omega T_2)[(1+j\omega T_3)(1+j\omega T_m)+(K_6K_7K_8K_9)]+(K_1K_2K_3)(1+j\omega T_1)(1+j\omega T_3)}$$

...BUT WILL IT FLY?

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The fastest and surest way to find out is to simulate the system and its actual operating conditions. Do it directly from the schematic by using the Servomation® Building Blocks.

You mock-up your system design with the proven electronic and electro-mechanical sub-systems and components of the Servomation Building Blocks (amplifiers, modulators, gears, inertia load discs, etc.). The system is connected by plugging into the external jack panels. Self-contained power and servo signal sources provide all the necessary test inputs to analyze your design. Complete evaluation of your system then can be made with the *Design Analysis and Test Bay* of the Building Blocks.

No programming . . . no need for highly-trained operators . . . no costly model shop prototypes. Modify design parameters by changing the external patch cord connections. You can simulate and test an *unlimited* number of control system designs with the Building Blocks.

In addition to functioning as a complete system simulating laboratory, the Servomation Building Blocks offer accurate, rapid debugging of existing systems or components. Self-contained and mobile, the Building Blocks can analyze complete industrial, aircraft and missile systems on the spot, without the need for multiple test units with varying accuracies.

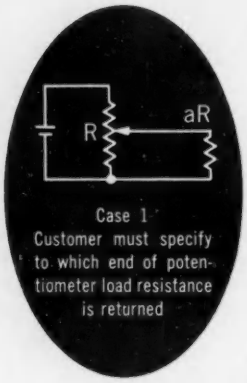
New Servomation Building Block Brochure

This new brochure gives you a complete description of the Building Block equipment. A typical servo-system design problem is discussed and mathematically derived, followed by a step-by-step analysis of the solution to this problem using the Servomation Building Blocks.

The brochure is yours upon request. Please specify on your company letterhead, SBB-9904-56C.

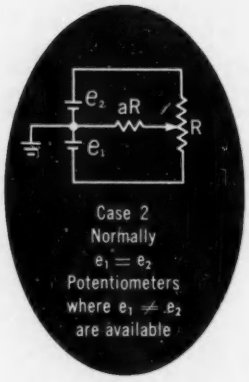
Load-Compensated Potentiometers

for Driving Current-Sensitive Circuits without Isolation or Buffering

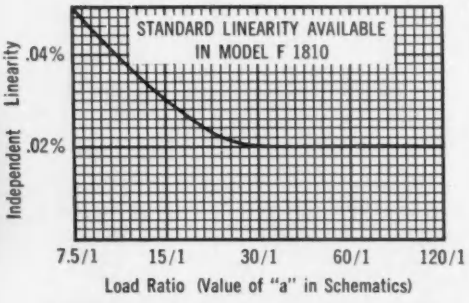


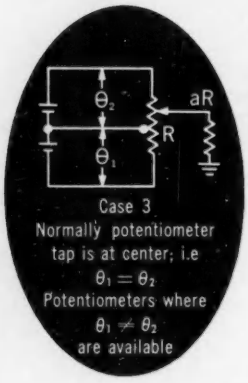
Case 1
Customer must specify to which end of potentiometer load resistance is returned

In a load-compensated potentiometer the current into the load is a linear function of shaft rotation. The load-compensated potentiometer is thus a shaft-rotation-to-current transducer, and may be used to drive current-sensitive devices without isolation or buffering. The scale factor of the current-rotation conversion varies directly with applied voltage and inversely with load resistance. The load ratio is permanently specified at the time of manufacture and is "built-in" the potentiometer.

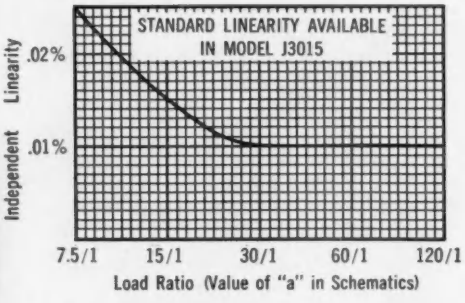


Case 2
Normally $e_1 = e_2$
Potentiometers where $e_1 \neq e_2$ are available





Case 3
Normally potentiometer tap is at center; i.e $\theta_1 = \theta_2$
Potentiometers where $\theta_1 \neq \theta_2$ are available



POTENTIOMETERS MEET NAS-710. Publication P102 describes in detail Analogue Controls Load-Compensated Potentiometers, including complete application information. Write today!

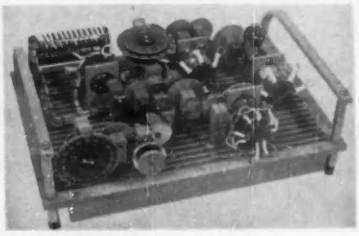
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Analogue Controls, Inc.
39 ROSELLE STREET, MINEOLA, N.Y.
PIONEER 2-8901

NEW PRODUCTS

matic action. As condensate rises in the trap, the float is held in place by a magnet mounted on the pivot arm. When the buoyant force of the condensate overcomes the magnetic attraction, the float snaps open a pilot valve. This arrangement permits rapid and efficient ejection of the condensate, with no air leakage, valve chattering, or excessive pressure drop. —Hankison Corp., Pittsburgh, Pa.

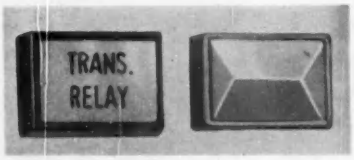
Circle No. 54 on reply card



400-CYCLE BREADBOARD

The assembly shown here is built from parts included in a new line of miniature servo mechanical components. This new line is designed especially for airborne 400-cycle servo systems. Parts include miniature slotted mounting plates, hangers, dial assemblies, mechanical and electrical stop assemblies, couplings, differentials, and gears. Gears are Class II, fit $\frac{1}{8}$ in. shafts, and are available in 64, 96, and 120 diametral pitches.—Reeves Instrument Corp., New York.

Circle No. 55 on reply card



FOR NEATER PANELS

Rectangular indicating lights, now available, permit designations to be engraved directly on the lens, eliminating the need for separate nameplates. Visibility of the designation is also improved. Lamp units, in all colors, are made with either flat or prismatic lenses, the latter having higher side visibility. Units are produced in two sizes: $1\frac{13}{32}$ by $\frac{31}{32}$ in., and $\frac{31}{32}$ by $\frac{11}{16}$ in.—H. R. Kirkland Co., Co., Morristown, N. J.

Circle No. 56 on reply card

(Continued from page 38)

vice-president. Both were formerly with the **Sandia Corp.**

▶A third new entry in the field, **Radiation Electronics Corp.**, has been organized at Chicago by George F. Warnke, Arthur E. Goldberg, and Herbert L. Berman, to develop and manufacture infrared detection systems, and to combine these systems with optical and electronic components for industrial and military applications. Warnke, president of the new company, was formerly chief of the **Electronics Div.** of **Chicago Midway Laboratories,** the University of Chicago.

▶New divisions of established companies are also in the news this month. One, **Minneapolis-Honeywell's** new **Boston Div.**, is made up of two sections, each once a division by itself. They are the **Semiconductor Products Section** (formerly the **Transistor Div.**) and **Instruments Section** (formerly the **Doelcam Div.**). Responsibility for all phases of the new division's operations is in the hands of George J. Schwartz, divisional vice-president and general manager. Offices will be split between Boston and Brighton, Mass.

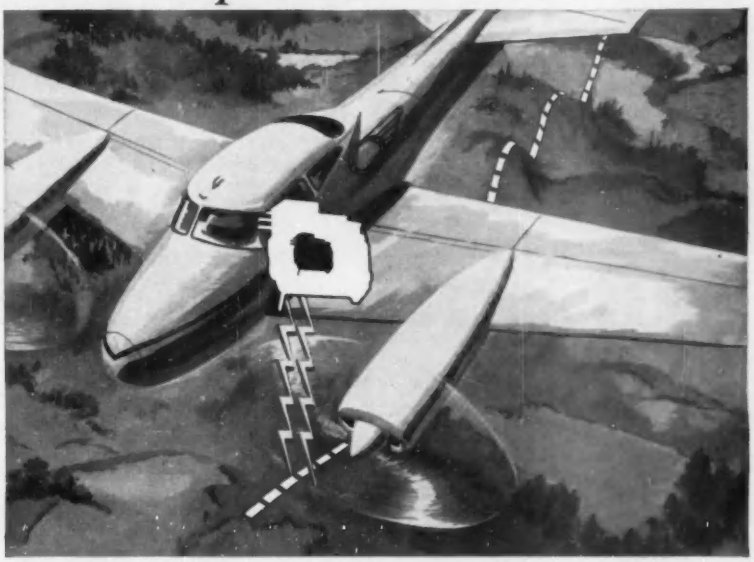
▶Another new division, the **Precision Nonlinear Potentiometer Div.** of **Ace Electronics Associates, Inc.**, is headed by William Lyons and Abraham Osborn, both formerly with **Technology Instrument Corp.** The new division will use manufacturing techniques developed by Ace for the production of subminiature precision wire-wound potentiometers and trimmers.

▶**North American Philips' Instruments Div.** has formed a new organization to be known as the **Process Control Systems Group,** which will do work in analysis and control devices. Initially, it will concentrate on the application of X-ray spectrographic analysis to the quantitative determination of elements in such areas as ore processing, chemical manufacturing, and measuring coating thicknesses. Group manager is Frank E. Farris, formerly with **Sperry Products, Inc.**, of Danbury, Conn.

▶A new **West Coast Div.** organized by **Magnetic Amplifiers, Inc.** at El Segundo, Calif., will engineer and manufacture magnetic and transistor servo amplifiers, dc power supplies, voltage regulators, and airborne servo systems.

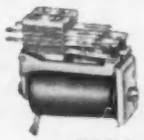
▶**Detectolab, Inc.**, which was founded in Chicago in 1952 and became an affiliate of **Borg-Warner Corp.** in 1955, has been consolidated into

Potter & Brumfield *engineering is in this picture*



Which P&B relay did Television Associates specify

FOR THEIR AIRBORNE COMPUTER?



MH Series



MB Series



MC Series

Surveys for pipe lines, electric transmission routes and microwave paths are now made from the air, by radar. Television Associates of Indiana, Inc. developed this speedy new technique—and the equipment—which provides clients with detailed profiles of the terrain to be crossed.

Part of the equipment, an intricate airborne computer, requires relays that are fast-acting, light weight, versatile. They must have high shock and vibration resistance and remain operative in temperatures ranging from −45°C to +85°C.

Modified MH relays by P&B were specified. These miniature relays meet all Television Associates' requirements and provide high reliability in a mighty small package. Challenging relay problems are solved daily at P&B. Twenty-five years of creative engineering are behind every P&B relay. Write today for our new catalog.

ENGINEERING DATA

SERIES: MH Miniature Telephone.

CONTACTS: Up to 18 springs, maximum 9 in each stack, forms A, B, C, D, E, X and Y. AC relays are limited to a maximum of 2 poles. Various contact material available.

VOLTAGE RANGE: DC - .05 to 110 V.— AC - 6 to 230 V. 60 cycle.

COIL RESISTANCE: 22,000 ohms maximum.

TEMPERATURE RANGE: High temperature range (DC) —55° C. to +135° C. Standard DC —55° C. to +85° C. Standard AC —45° C. to +40° C. Other temperature ranges available to specification.

TERMINALS: Standard pierced solder lug holes will take (2) No. 18 hook-up wires. Adaptable for printed circuits.

ENCLOSURES: Dust cover plus wide range of hermetically sealed covers and types of terminations.

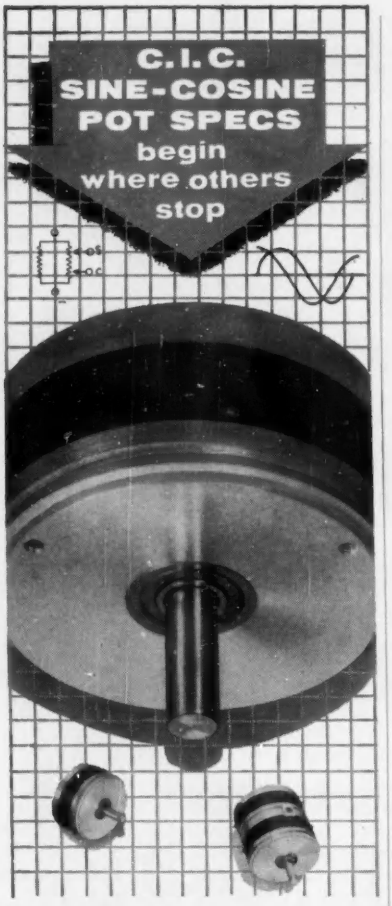
DIMENSIONS: 1-9/16" L. x 25/32" W. x 1-3/8" H. (4c Relay).

P&B RELAYS AVAILABLE AT MORE THAN 500 DISTRIBUTORS IN ALL PRINCIPAL CITIES

Potter & Brumfield, inc.

PRINCETON, INDIANA *Subsidiary of* AMERICAN MACHINE & FOUNDRY COMPANY

Manufacturing Divisions also in Franklin, Ky. and Laconia, N. H.



Infinite resolution and absolute dependability distinguish CIC ultra-precise Potentiometers. In the generation of the sine wave CIC Pots provide smooth, reliable performance, distortion free at all angles of rotation.

CIC carbon film Sine-Cosine Pots, the proven product of a unique research program, provide greater accuracy in smaller case sizes. Sizes range from 1" to 5" diameter with corresponding best conformities from .3% to .03%. Compensation for loading can be provided with **no loss of performance.**

At speeds in excess of 1,000 r.p.m. CIC guarantees life in excess of two million revolutions.

Many firms with critical specifications for industrial instrumentation, military fire control and flight guidance equipment rely only on CIC Potentiometers.

Our highly qualified engineers are ready to discuss your specific requirements with you. Call us today.

"For Precision Performance ... specify CIC"

Detailed Technical Data Sheets available on request.

CIC COMPUTER INSTRUMENTS CORPORATION

IVanhoe 3-8200

92 Madison Ave. • Hempstead, Long Island, N. Y.

WHAT'S NEW

B-W's **BJ Electronics,** the electronics division located at Santa Ana, Calif. The nuclear instruments manufactured by Detectolab will continue to be marketed under its name.

▶As part of its program to expand in the field of industrial and military relays and controls, **Hedin Tele-Technical Corp.** of Mountain View, N. J., has changed its name to **General Automatic Corp.**

Companies A-Building

▶An addition (31,000 sq ft) to its Commack, N. Y., **Precision Components** plant, by **Norden-Ketay Corp.** The new quarters will increase working space at Commack to more than 85,000 sq ft.

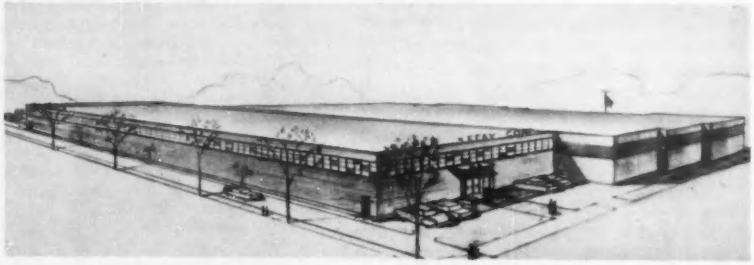
▶A new plant (16,200 sq ft) in Folcraft, Pa., in suburban Philadelphia, for **Hetherington, Inc.,** which will use the extra room to meet growing demands on all of its departments. The one-story structure will house administrative, sales, and engineering offices, and testing and assembly units.

▶A building (28,000 sq ft), located near Pine Castle AFB, Orlando, Fla., for the **Instrumentation Div.** of **Radiation, Inc.,** which will use the facility for offices, laboratories, and hangar space for test-vehicle instruments. The quarter-million-dollar addition brings Radiation's plant capacity at Orlando and Melbourne, Fla., to 120,000 sq ft.

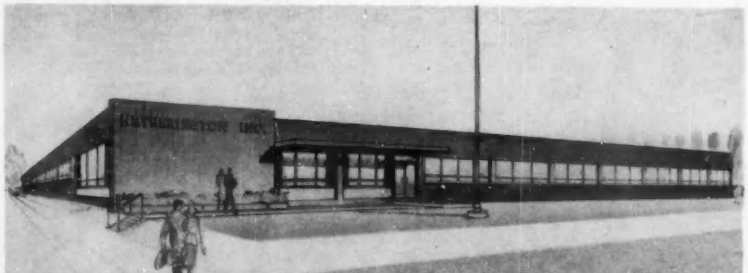
▶A two-story addition to its Acton, Mass., plant, by **Technology Instrument Corp.** Features of the new section, which is expected to increase capacity by as much as 100 percent, include a filtered air system for control of dust and humidity, and an overall design that will permit orderly flow, continuous testing, and close quality control. According to Hollis Gray, TIC's engineering sales manager (CtE, July '56, p. 80), rising demands for the company's precision potentiometers have brought production increases amounting to ten times the production capacity of just six years ago.

▶The first (44,000 sq ft) of four major buildings for **General Atomic's John Jay Hopkins Laboratory** for Pure & Applied Science in San Diego, Calif. The laboratory now going up will be for nuclear and engineering experiments and for laboratory service facilities; the others will house additional laboratories, executive offices, a library, and technical and lab service facilities. Two temporary buildings are already being constructed on the site by the **General Dynamics Corp.** division for critical assembly experiments in connection with development of its nuclear reactor.

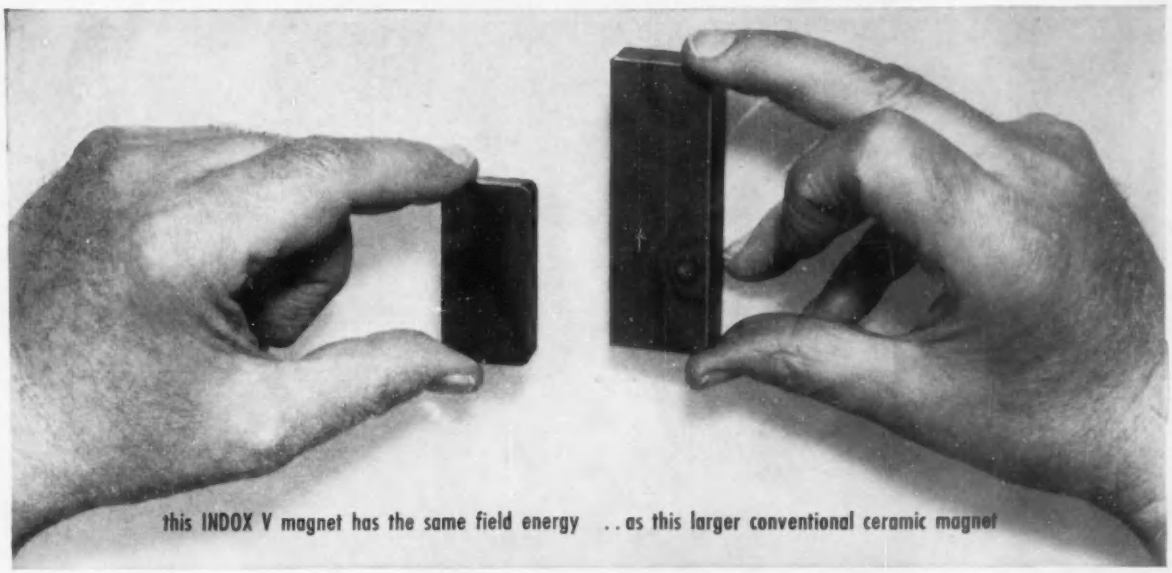
▶A million-dollar-plant (55,000 sq ft) in eastern Nassau County, N. Y.,



Norden-Ketay spreads out in Commack, N. Y.: 85,000 sq ft for precision components.



Hetherington, Inc., expands in suburban Philadelphia: new plant shares increasing load.



NEW, high energy Indox V ceramic permanent magnets

..they're 3½ times stronger than conventional ceramic magnets

Indox V — another first from the research and development laboratories of The Indiana Steel Products Company — is available to magnet users *immediately*. This unique, new, magnetic material offers these important advantages . .

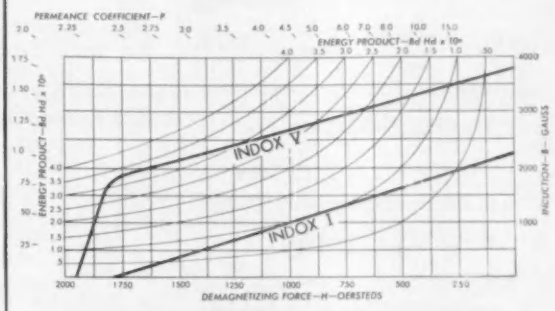
Indox V requires no critical materials. It is a highly oriented barium ferrite . . using inexpensive, noncritical, raw materials that are constantly available. Shortages in times of emergency cannot occur.

Indox V requires less space, weight to do same job. Volume and weight comparisons show that the energy of Indox V far exceeds Indox I . . and is comparable to Alnico V, the strongest permanent magnet material commercially available.

Indox V offers high resistance to demagnetization. Indox V magnets can be designed for applications where extremely high demagnetizing forces exist . . without irreversible losses occuring. This means it can be used where other types of magnets have been impractical . . for example, in stators of medium-size electric motors where electromagnets are now being used.

..ideal for:

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- Traveling wave tubes
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Comparison of demagnetization and energy product curve for conventional Indox I ceramic magnets and the new, high energy Indox V magnets.

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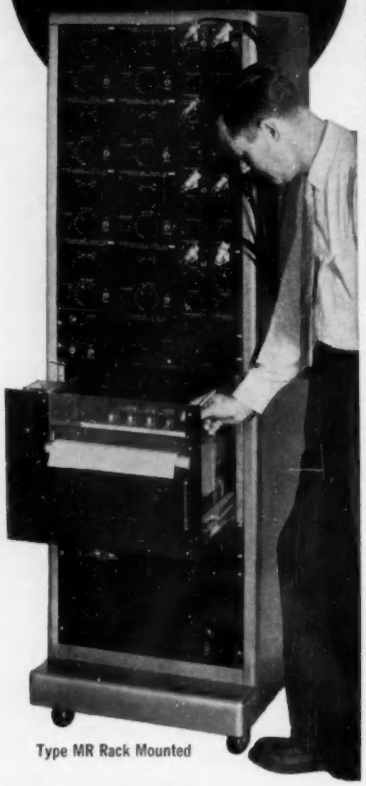
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WHAT'S NEW

for **Servomechanisms, Inc.**, which will use the structure for the engineering and production operations of its **Subsystems Group**, now undergoing an expansion. Completion is set for late this year.

▶ Development by **Fischer & Porter Co.** of two tracts of land in central Bucks County, Pa., eight miles from the home office at Hatboro, Pa. The larger of the two sites (120 acres) will accommodate contemplated offices, research laboratories, and additional production facilities, the smaller (65 acres) a recreational area, including an 18-hole golf course, tennis courts, and a club house.

▶ A $2-million manufacturing plant (180,000 sq ft) completed at Milford, Conn., for its **Bridgeport Thermostat Div.**, by **Robertshaw-Fulton Controls Co.** Being produced there are precision instruments and components for industry and aviation, as well as such bellows-type items as automotive thermostats and temperature controls.

▶ A new home (20,000 sq ft) in El Monte, Calif., for **Crescent Engineering & Research Co.** The new location provides three times the amount of space formerly available and room for even further expansion.

▶ Expansion of **Behlman Engineering Co.'s** Burbank, Calif., plant, doubling floor space for production of prototypes for electronic, mechanical, and optical engineering projects, as well as Behlman's "Invertron", an electronic ac power source for special-cycle testing.

▶ A new division, and a new manufacturing plant to go with it, outside of Phoenix, Ariz., for **Sperry Rand Corp.** The division: **Sperry Phoenix Co.**; the plant: a home for development and production of advanced electronic flight and engine control systems for drone and manned aircraft. A $2-million unit (75-100,000 sq ft) will be the first to go up.

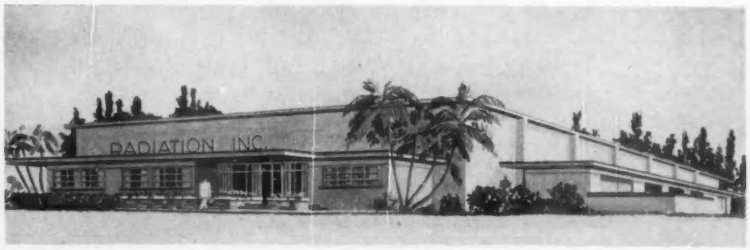
▶ An electronic center (800,000 sq ft) in Rochester, N. Y., for **Stromberg-Carlson Div.** of **General Dynamics Corp.** By centralizing all electronic manufacturing, the former Bond Stores plant will free Stromberg-Carlson's main unit (a $5-million factory, now a-building) for exclusive production of telecommunication equipment. The move to Rochester should be completed by April.

Important Moves by Key People

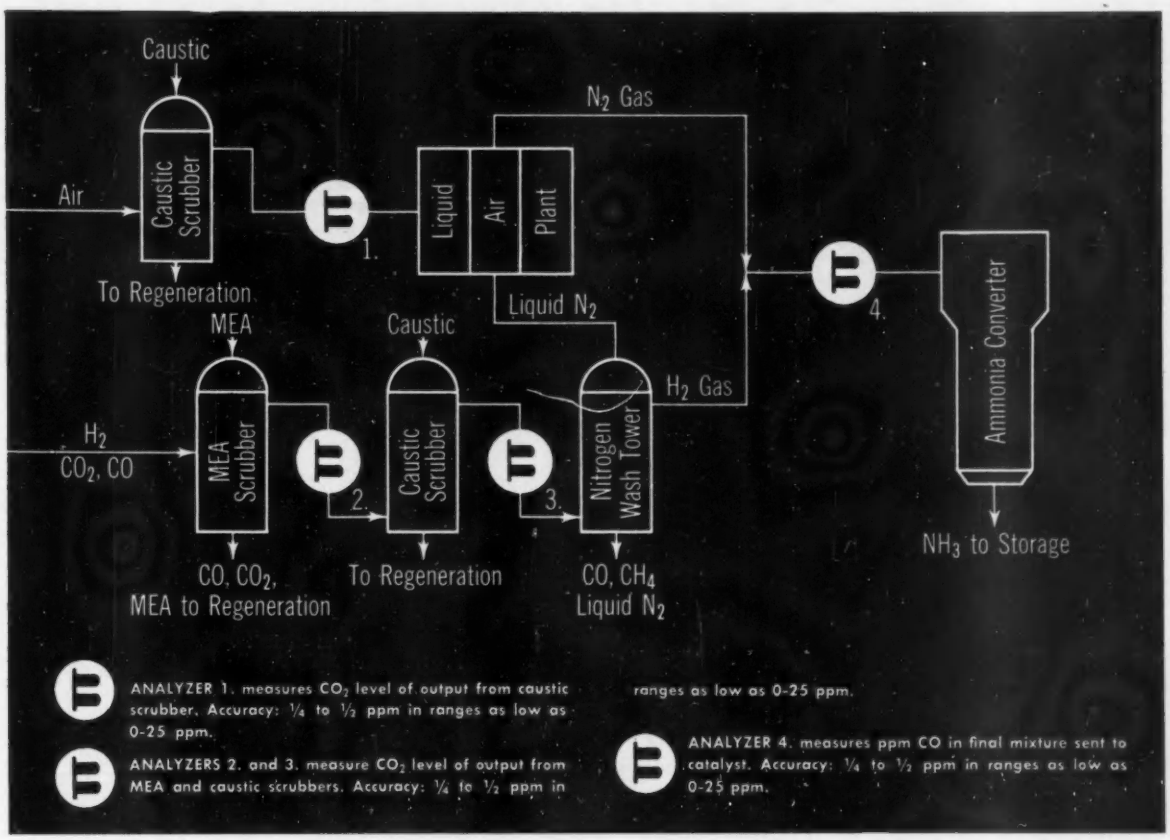
▶ **David Wolkov**, the new chief engineer of Midwestern Instruments, Inc., comes to the Tulsa, Okla., company from Superior Magnetic Co. of Long Island City, N. Y., where he held a similar position. He has also been a consulting engineer and assistant chief in the engineering office of the Ordnance Tank Command.

▶ **George W. Borg**, who has been both chairman and president of The George W. Borg Corp. of Delavan, Wis., has transferred his duties as president to **Byron C. Booth**, formerly president of The Borg Equipment Div. At the same time **G. Marshall Borg** becomes vice-chairman of the board, **Ralph A. Ackerman**, formerly production manager, becomes manager of the Equipment Div., and **L. C. Whitford** becomes divisional contract administrator. The changes will permit George Borg, who was one of the founders of the Borg-Warner Corp., to devote more time to his company's corporate policies.

▶ **Thornton C. Fry**, a mathematician widely known for his contributions to the mathematical theory of probability and author of the book, *Probability and its Engineering Uses*, has been named senior consultant for Remington Rand's Univac Div. Fry, who recently retired as assistant to the president of Bell Laboratories, is a fellow of the AIEE, the American Physical Society, and the Institute of Mathematical Statistics, and a holder of the Presidential Certificate for



Radiation, Inc., grows in Orlando, Fla.; quarter-million-dollar home for instrumentation.



in a 250 ton per day ammonia plant . . .

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. . . save $16,000 a year

Perkin-Elmer *continuous* infrared analyzers can increase the efficiency of *your* process – by doing away with "analytical lag," moving the laboratory right out to the process line. Take this example of an ammonia plant.

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Analyzers 2. and 3. measure the CO_2 level of output from MEA and caustic scrubbers. At this level, the equipment is paid off in less than a year.

Analyzer 4. measures ppm of CO in final mixture sent to the catalyst. With proper control of CO level, $8,000 to $10,000 can be saved by extending catalyst life. The analyzer pays for itself in 6 months!

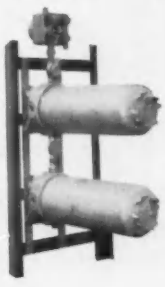
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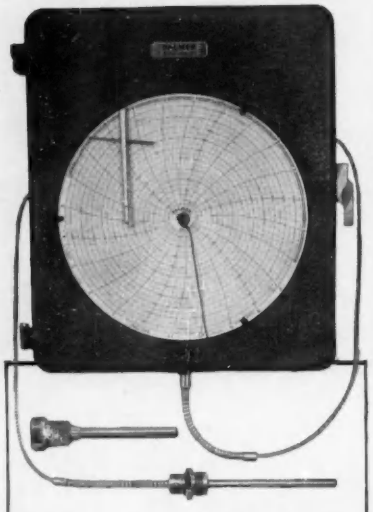
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WHAT'S NEW

Merit for his wartime work in fire control.

▶ Daystrom Systems, the new La Jolla, Calif., division of Daystrom, Inc., has taken on **Eric Weiss,** formerly senior staff physicist for Hughes Aircraft Co., as a member of its engineering staff. Weiss, an important figure in computer design, is credited with Northrup's Maddida 44A, the first compact, electronic digital computer, Computer Research Corp.'s special-purpose computer, decimal differential analyzer, and high-speed printer, and other developments. Establishment of the new Daystrom division was reported in CtE last October, page 155, when its unique "reason for being" was also detailed.

▶ Top-level changes at Sperry Rand's Sperry Gyroscope Co. spotlight **Carl G. Holschuh,** named president and general manager; **Carl A. Frische,** named executive vice-president, and **E. U. DaParma,** named vice-president of operations for all product divisions. Holschuh, most recently executive vice-president and general manager of the company, developed the Sperry gunsight and turret used on the B-17. He succeeds **Charles M. Green,** who has retired. Frische has headed Sperry's headquarters operations since 1954. He is a fellow of the IRE. DaParma has been vice-president in charge of manufacturing since 1952.

▶ **James D. McLean** has resigned as vice-president and general manager of Philco's Government & Industrial Div. to become president of Hoffman Laboratories, Inc., a subsidiary of Hoffman Electronics Corp. He succeeds **John B. Moss,** a director of the corporation, who becomes chairman of Hoffman Labs' executive committee. Under McLean will be more than 2,200 employees, including 400 engineers, and the 12 engineering service centers and field offices in the U.S. and Alaska.

▶ In his new job as director of research for Electrical Communications, Inc., **Donald E. Bently** will be in charge of development of transistorized devices for telephone, radio communications, and industrial control applications. Before joining ECI, he was with Donner Scientific Co. (project engineer), Electronic Products Corp. (senior engineer), and North American Aviation (research engineer, Autonetics Div). He has his own R&D laboratory in Berkeley, Calif.

▶ The new vice-president and general manager of Sperry Rand's Ford Instrument Co. is **Charles S. Rockwell,** who has been with the company since 1943, most recently as vice-president and works manager of the Farragut Div.

▶ Feedback Controls, Inc., has appointed two new vice-presidents,



David Wolkov



B. C. Booth



T. C. Fry



Eric Weiss

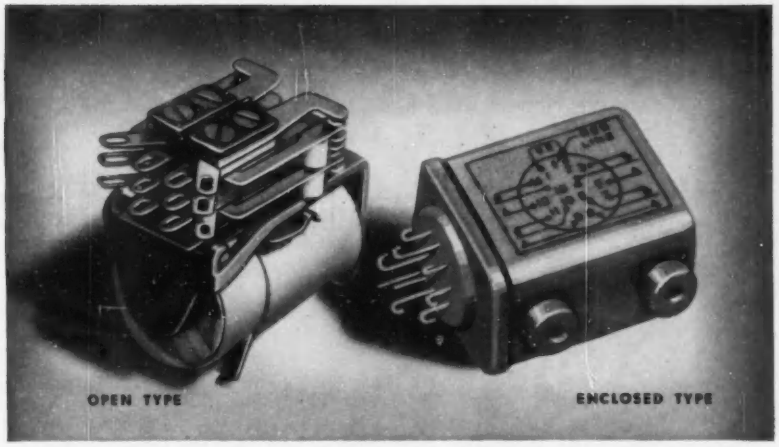


E. U. DaParma



C. G. Holschuh

R-B-M Miniature Multipole Relays of Proven Reliability



Light weight, Small Size Open and Hermetically Sealed Types for Electronic and Communication Application

APPLICATION: R-B-M Miniature Multipole Relays are used where the prime factors in switching electronic circuits are small size, light weight and reliability. These proven designs are produced for switching low power circuits, low capacitance circuits and power circuits. 125° C insulation now available on some versions. Coils can also be designed for plate circuit.

CONSTRUCTION:

Magnet Frame—Four sizes available on open type relays and three sizes on hermetically sealed type.

Contacts—Cross-bar palladium welded to nickel silver springs or button contacts on Beryllium copper springs.

Terminals and Mountings—Glass headers provided with either solder or plug-in type terminals with many various types of mountings available. Octal type plug-in headers can be provided on the HL enclosure. Plug-in terminals to fit either 9 or 14 pin standard sockets. Maximum of 14 pins for solder connections.

TYPICAL SPECIFICATIONS*

Open	Maximum Coil Resistance (OHMS)	Minimum Power Requirements Per pole at 25° C (WATTS)	Maximum Contact Form With rated current at 32 V.D.C. or 115 V.A.C. (non-inductive load)	Maximum Coil Watts	Enclosed
SM	9,000	.2	4 PDT 5 Amps. or 3 Amps. 6 PST 3 Amps.	3.75	HSM
SMD-2	9,000	1.0	SPNO Parallel Contacts Make 80 Amps. Break 20 Amps. at 32 V.D.C.	3.75	HSMD-2
SC	18,500	.16	4 PDT 5 Amps. or 3 Amps. 6 PST 3 Amps.	4.5	HPSC
SA	18,500	.14	4 PDT 5 Amps. or 3 Amps. 6 PST 3 Amps.	4.5	HLSA
SM-RF	9,000	.2	SPNO, SPDT, DPNC, SPNC, DPNO	3.75	HSM-RF HLSM-RF
SAD-2	18,500	1.0	SPNO Parallel Contacts. Make 80 Amps. Break 20 Amps. at 32 V.D.C.	4.5	HLSAD-2

*Other ratings and specifications available.

For additional information write for Bulletin No. 1050

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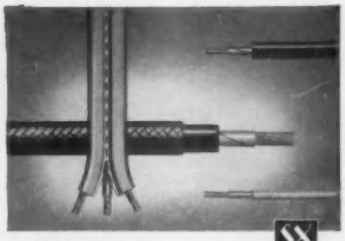
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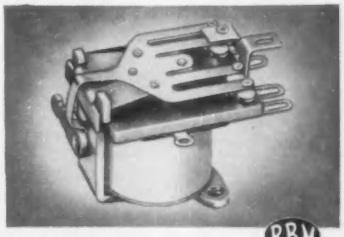
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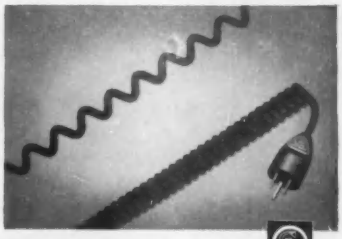
Wire and Cable Division
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R-B-M "Control" Division
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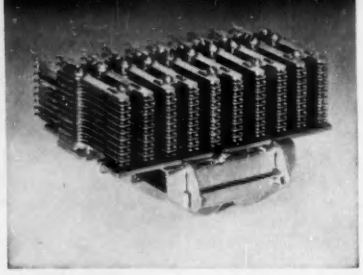
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WHAT'S NEW

Theodore P. Heuchling for engineering, and **Alvin C. Brodie** for sales. Heuchling, formerly chief engineer of the company, had prior experience with the MIT Servomechanisms Laboratory and with Ultrasonic Corp. Brodie came to Feedback Controls last year after several years with the same MIT laboratory as well as with California-Texas Oil Co.

▶ CDC Control Services, Inc., has appointed George Gumas chief systems engineer and has brought in Abraham Fuchs, formerly senior engineer of the Air Arm Div. of Westinghouse Electric Corp., to replace Gumas as head of the Analytical Dept. Before joining CDC in 1953, Gumas was with The M. W. Kellogg Co.

▶ **Clarence Zener,** the new director of the Westinghouse Research Laboratories, has been acting director for the past year and was an associate director before that. His promotion coincides with the lab's move to new facilities in Churchill Burough, ten miles east of Pittsburgh, Pa. Zener is the author of a theory of ferromagnetism which explains why certain materials are strongly magnetic, and of the Zener effect, a theoretical explanation of the electrical breakdown in semiconductors such as geranium and silicon. He joined the laboratory in 1951 after serving as a teacher in several universities.

▶ Two new appointments by Systems Laboratories Corp. involve **James A. Marsh,** who becomes vice-president, and **Richard H. De Lano,** secretary, who becomes director of the Systems Integration Div. Marsh, who is well-known in the field of radar systems, was formerly Autonetics radar group leader at North American Aviation, where he directed work on all missile and manned aircraft antenna designs at the Downey, Calif., plant. De Lano, who worked on the Falcon air-to-air guided missile as senior staff physicist at Hughes Aircraft Corp., is a senior member of the IRE and chairman of its Los Angeles Professional Group on Information Theory.

▶ Another new divisional director is **B. Lazich,** who takes charge of the Research & Engineering Div. of Filtors, Inc., of Port Washington, N. Y. Lazich comes from the Robertshaw Research Center in Irwin, Pa., where he specialized in work on electrical and thermostatic control devices. He is a holder of more than 30 patents in relays and other components.

▶ Three companies report they have new chief engineers. The companies and the men they have appointed are: Universal Atomics Corp., which has picked **Alan R. Pearlman,** a specialist in transistor circuitry who was formerly assistant director for technical services of Clevite Transistor Products; Nader Mfg. Co., whose new man is **Leon F. Edelson,** formerly a research engineer with Jet Propulsion Laboratory—his appointment completes a staff realignment that saw former Chief Engineer **Robert T. Schultz** become general manager, **James P. Nader,** formerly with Motordyne, Inc., sales manager, and **Paul Pulver** purchasing director; and Barton Instrument Corp., whose choice, **George Miller,** has had previous experience with Fluor Corp., Askania Regulator Co., and the University of Chicago (research fellowship).

▶ Recently promoted by Varian Associates were **Forrest Nelson,** formerly product engineer, now head of the Advanced Development Group in the Instrument Div.'s Research Dept., and **Robert H. Watson,** now chief product engineer in the same division. Watson came to the company in 1955 from Ryan Aeronautical Co., where he had been an electronics group engineer.

▶ A fund donated by **W. R. G. Baker,** vice-president of GE and chairman of the IRE's Professional Groups Committee, is being used by the IRE



J. D. McLean

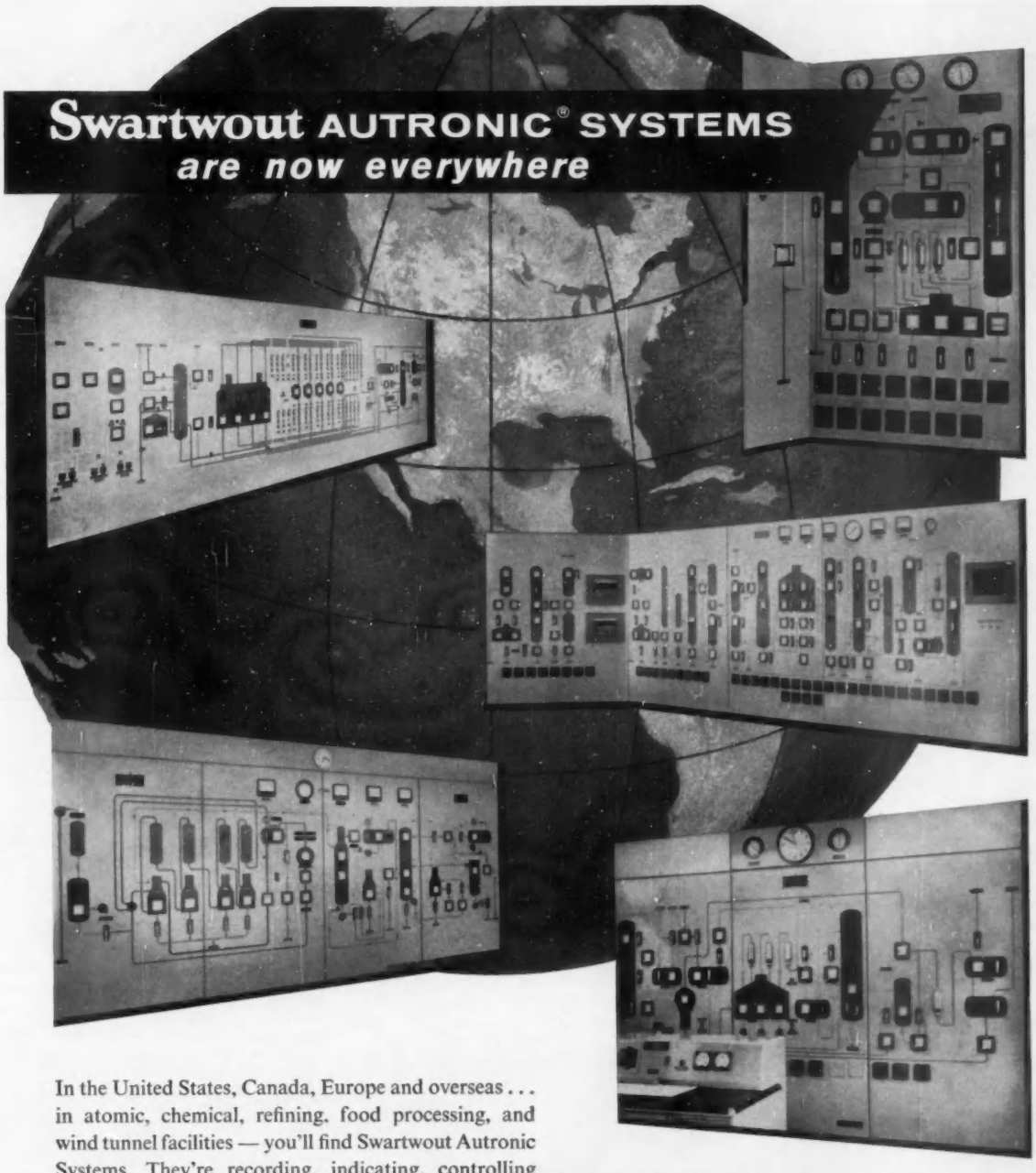


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are famous for accuracy, ruggedness, dependability and fast delivery in commercial and military uses. They are precision-machined, with anodized aluminum bodies, line-reamed phosphor bronze, ball or jewel bearings, centerless-ground stainless steel shafts, and gold-plated fork terminals; fully sealed and fungus-proofed. To meet your requirements Waters pots can be furnished ganged, tapped, servo or bushing mounts, with various electrical and mechanical angles, optional shaft locks, anti-rotation pins, 0 rings, and custom shaft or servo dimensions.

Series AP ½ — 2 watts continuous at 80°C; resistances 10 to 100,000 ohms, 5% tolerance standard; diameter ½", depth ½" standard, weight ¼ ounce; fully sealed for potting.

Series LT/LLT ⅞ — One watt at 80°C; resistances 100 to 100,000 ohms, ball or jewel bearing, for use in computers, servos, and selsyns where minimum torque is required. Weight is only ½ ounce; MAXIMUM torque is 0.01 inch-ounce per section. Ganging to six decks, internal clamps hold ⅞" diameter. Standard linearity 0.5%, on special order 0.25% above 1K; toroidal winding allows winding angles to 360°, standard is 354°.

Series RT/RTS ⅞ — 3 watts continuous at 80°C; resistances 10 to 100,000 ohms; diameter ⅞", depth ⅜", weight ½ ounce; standard linearity 2%.

Series AP1⅛ — 4 watts continuous at 80°C; resistances 10 to 150,000 ohms; diameter 1⅛", depth ½", weight less than ¾ ounce; standard linearity 1%.

Waters has advanced facilities for the design and manufacture of miniature toroidal potentiometers and windings for use in equipment of special design.

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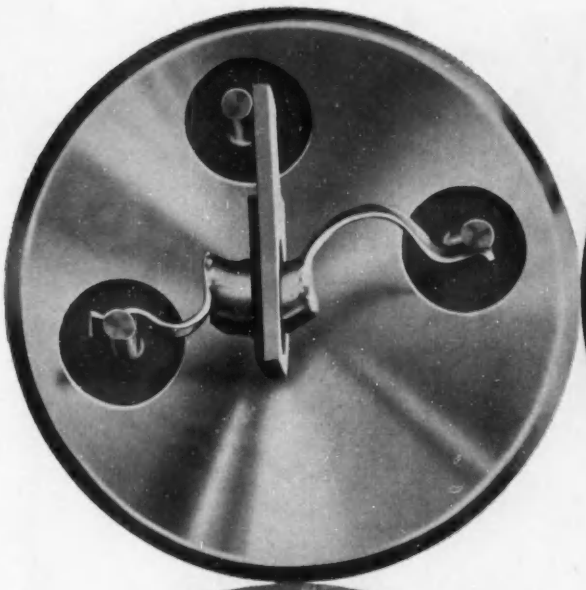
to finance a new W. R. G. Baker Award for the best paper published in the institute's transactions. Three men whose papers appeared in various "IRE Transactions on Audio" share the first award. They are: **R. J. Kircher,** Hughes Aircraft Co. ("Properties of Junction Transistors", No. 4, July-August, 1955); **R. L. Trent,** Bell Telephone Laboratories ("Design Principles of Junction Transistor Audio Amplifiers", No. 5, September-October, 1955); and **D. R. Fewer,** Bell Telephone Laboratories ("Design Principles for Junction Transistor Audio Power Amplifiers", No. 6 November-December, 1955).

▶ **D. A. Buck** of MIT's Electrical Engineering Dept. is slated to receive the 1957 Browder J. Thompson Memorial Prize for his paper, "The Cryotron—a Superconductive Computer Component", which appeared in the April 1956 issue of the "Proceedings of the IRE."

▶ Another award, this one the Lawrence B. Sperry Award of the Institute of Aeronautical Sciences, goes to **George F. Jude,** director of flight control engineering for Sperry Gyroscope Co., "for significant contribution to the advancement of precision automatic flight and safe all-weather flying". Jude led a team of engineer-scientists in developing the SP-30 jet-airliner flight-control system, now standard on the Douglas DC-8 and on order by 11 airlines.

▶ Named to "policy-making" status at Topp Industries, Inc., is **John L. McLucas,** the new vice-president and technical director. Topp Industries owns McLucas' former company, Haller, Raymond & Brown, Inc., of State College, Pa. McLucas' across-the-board responsibility for research and development will encompass Topp, HRB, and Heli-Coil Corp. of Danbury, Conn., which recently was acquired by Topp. McLucas' quarters will be at State College. He was with the Air Force Research Laboratory at Cambridge, Mass. (servo system design) and Penn State University (graduate assistant in physics) before joining HRB, where he became vice-president and technical director in 1950.

▶ **Harvard L. Hull,** who has been president of Farnsworth Electronics Co. since 1954, goes to Litton Industries as one of two new vice-presidents. The other is **George Friedl Jr.,** formerly v-p and director of advanced planning for Link Aviation, Inc. Hull worked on the Manhattan Project and at Argonne National Laboratory be-



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In computer or in other applications where current must be amplified in either direction, you can now specify General Transistor's new GT-34S bi-directional transistor.

As developed by GT, this symmetrical transistor can also be used as a bi-directional switch when placed in series with the load. For greater reliability, to save production time, and for compactness you should examine GT's-34S . . . another reason for General's leadership in the manufacture and development of transistors for computers.

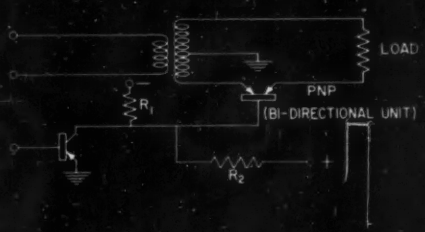
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GT's-34S magnified 10½ times.

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Maximum emitter to base voltage	40 volts
Peak current	½ amp.

DC current gain is > 10 when I_b = 20 ma, Vce ≦ .3 V.



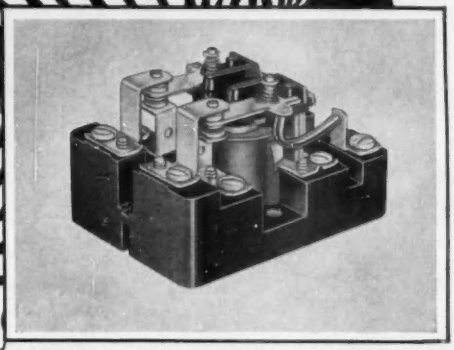
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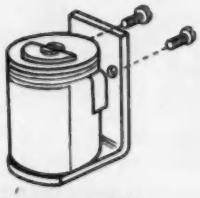
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WHAT'S NEW

fore his appointment as vice-president for R&D by Capehart-Farnsworth Co. in 1953. A year later he became president of Farnsworth Electronics. He was 1955 chairman of IT&T's Technical Committee on Nuclear Energy. Friedl, a former president of Librascope, Inc., has also been with General Precision Corp., Librascope's parent.

▶ Other vice-presidents recently appointed: **Cecil R. Russell,** J. B. Rea Co., Inc.; **B. M. Wolfframm,** Magnetic Research Corp.; **H. T. Sawyer,** The Kybernetes Corp., and **W. W. Gilmore,** Minneapolis-Honeywell Regulator Co. Russell came to Rea in 1953 from Logistics Research, Inc., where he had been vice-president for engineering. Before that he was with Northrop Aircraft, Inc. Wolfframm, a specialist in magnetic circuits and components, joined MRC in 1954 after experience in the Armament & Flight Research Laboratory, Wright-Patterson AFB, and North American Aviation, Inc. Sawyer, a Kybernetes man since 1955, formerly was with RCA and Bailey Meter Co. Gilmore, president of Honeywell's Micro Switch Div. since 1950, will continue in that post.

▶ New chief of Acoustica Associates, Inc., is **Donald R. Church,** formerly a staff member of the Ultrasonic Development Group of the Naval Ordnance Laboratory at Silver Springs, Md. He moves into his new position at the same time as **Morris Kenny** becomes project engineer of Acoustica's Air Force missile systems development program and **Martin A. Damast** becomes senior electronic engineer. Kenny also comes from the Silver Springs Laboratory, Damast from Airborne Instruments Laboratory.

▶ **Cleo F. Craig,** whose election as chairman of American Telephone & Telegraph Co. highlights a series of top-level changes in that organization, fills a post that has been vacant since the retirement of **Walter Gifford** in the late 1940's. Craig, president of AT&T since 1951, is succeeded in that position by **Frederick R. Kappel,** formerly president of Western Electric Co., while the helm of the latter company is taken by **Arthur B. Goetz,** Western Electric's former vice-president for manufacturing.

Going down the line, Goetz's successor is **Paul A. Gorman,** formerly vice-president for finance, and Gorman's is **Paul R. Brousse,** who has been comptroller of Western Electric's Manufacturing Div. Other new Western Electric vice-presidents are

IMPORTANT ACHIEVEMENTS AT JPL



Engineering Teamwork in Missile Development

The Jet Propulsion Laboratory is a stable reseach and development center located north of Pasadena in the foothills of the San Gabriel mountains. Covering an 80 acre area and employing 1700 people, it is close to attractive residential areas.

The Laboratory is staffed by the California Institute of Technology and develops its many projects in basic research under contract with the U.S. Government.

Opportunities open to qualified engineers of U.S. citizenship. Inquiries now invited.

Engineers and scientists interested in a wide range of activities will appreciate the fluid character of the research and development projects in progress at the Jet Propulsion Laboratory. These projects include research in the fields of Electronics, Physics, Applied Mathematics as well as the design, development and analysis of guided missile systems.

These men, though individually responsible, work together as a thoroughly integrated team on all of the aspects of the entire missile system instead of concentrating on certain highly specialized missile components.

Since this work includes projects involving guidance, electronics, systems analysis, structures, propulsion etc., which are constantly influenced by continuing Laboratory research, the comprehensive program contains problems which are challenging to individuals with interests in virtually every phase of engineering and science.

The great diversity of activity and constant progress being made in the various fields of endeavor by the staff of the Jet Propulsion Laboratory has proved to be a stimulating attraction to qualified people interested in pioneering in basic research, applied research and development engineering in the guided missile field. The result of this has been to bring together a congenial group of forward-looking engineers and scientists who are intensely interested in the pioneering projects now in progress at the Laboratory.

Additional men of this type are needed and if you are interested and feel you are qualified, send your resume today for immediate consideration.

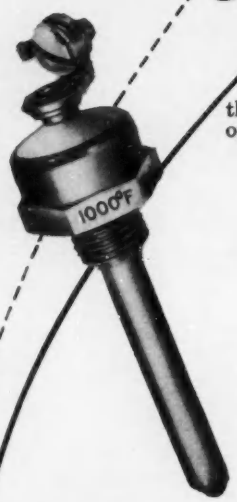
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New CPI thermal switch is *Light and Lively*

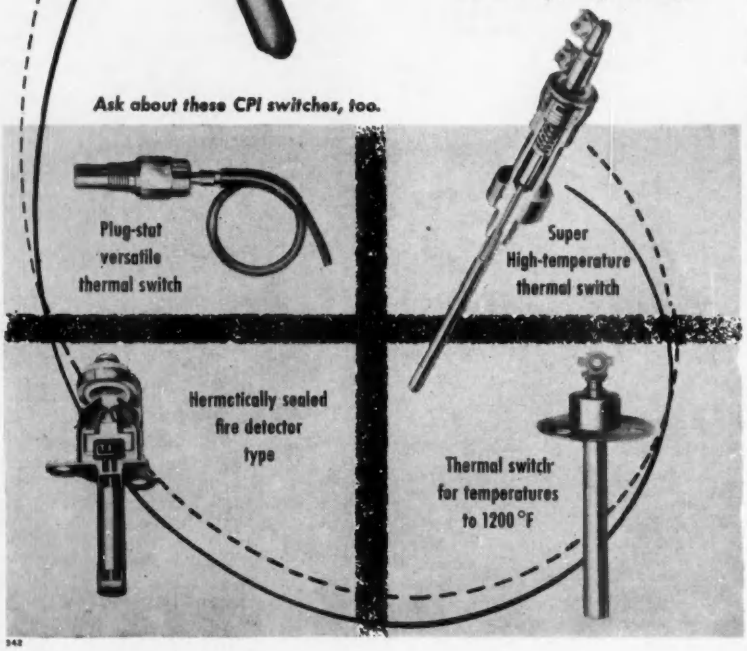


This new lightweight (weighs less than one ounce) thermal switch features an operating differential of plus or minus only one degree with extremely fast response.

With an effective calibration temperature rating from −20°F +1000°F, it will even operate accurately when subjected to momentary undershoots to −80°F and overshoots to as high as 2000°F.

Wherever fast-acting, sensitive, thermally responsive regulation is required for control of dangerously high or low temperatures, this "LIGHT and LIVELY" switch will do the job accurately, dependably.

Ask about these CPI switches, too.



Ask our representative to tell you how CPI can help you solve your temperature control problem—and remember—when temperatures are high (or low) you can depend on CPI.
Write for complete engineering data.
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HARRISON, N. J.

WHAT'S NEW

Clyde C. Randolph (manufacturing operations for the western area), formerly works manager of the Hawthorne Works, succeeding **Reese F. Clifford**, retired; **Noble Armstrong** (distribution), formerly distribution manager; **James N. Cost**, (installation), formerly installation operating manager; and **Charles D. Dugan**, who continues as comptroller.

► The new head of applications engineering for Raytheon Mfg. Co.'s Receiving Tube Div. is **Vinton K. Ulrich**, formerly general sales manager of David Bogen Co., Inc. Previous affiliations include Hytron Radio & Electronics Corp., National Union Radio Corp., and the Office of Scientific Research & Development, which he served as consultant during the last war. He is a senior member of the IRE.

► **Dr. Paul J. Flory**, whose work in physical chemistry, primarily in high polymers, has brought him international honors, has taken the helm of Mellon Institute's investigational activities. He will remain professor of chemistry and acting chairman of the Dept. of Chemistry of Cornell University, posts he has held since 1948 and 1950, respectively. He is also a consultant to du Pont. His long career includes many high-level positions in industry and education, and many citations. The part-time office at the institute is a new one, having been established shortly after the recent retirement of President **Edward R. Weidlein.**

► Following a general personnel shift at Taylor Instrument Cos., **Harry G. Olson** becomes divisional sales manager in charge of industrial instrument sales, **Warren C. Gray** becomes home-office divisional sales manager in charge of instrument sales, **Donald Warner,** head of the Greensboro, N. C., branch, **Robert B. Reynolds,** industrial sales manager at Chicago, **John Humphrey** manager at Philadelphia, and **Ernest A. Capelle** manager of the new Washington-Baltimore office.

► New head of the Data Processing Section of Ramo-Wooldridge's Management Sciences Dept. is **Neal J. Dean,** formerly in charge of the Applications Group for the Laboratory for Electronics' business-machines program. His appointment coincides with those of **Melvin L. Baker** and **James R. Woodbury,** who joined R-W's Control Systems Div.

► Technitrol Engineering Co. has named **Louis J. Alvare,** formerly chief mechanical engineer, director of en-

gineering in charge of contract work; **George Hand,** formerly chief electrical engineer, director of product research; **Gerard J. Bradley,** director of contract manufacturing, and **Robert K. Brewer** director of product manufacturing.

▶ **Ralph S. White,** formerly assistant manager of the Liston-Becker plant of Beckman Instruments' Scientific Instruments Div. at Stamford, Conn., has been named manager of research and engineering for Beckman's Spinco Div. at Belmont, Calif. Before going to Stamford, White was chief adminstrative engineer for the SI Div. at Fullerton, Calif.

▶ Increasing need for special-purpose computing and data-processing systems has prompted IBM to establish a Special Engineering Products Div., which will not only develop new components, machines, and systems, but will modify a standard IBM apparatus to meet specific requirements. General Manager **Jerrier A. Haddad,** formerly director of advanced machine development, is at 34 a veteran of key IBM projects: he was design and construction chief for the 701 computer, the first of the 700 line. **Kenneth N. Davis Jr.,** administrative assistant to the executive vice-president, becomes controller of the division.

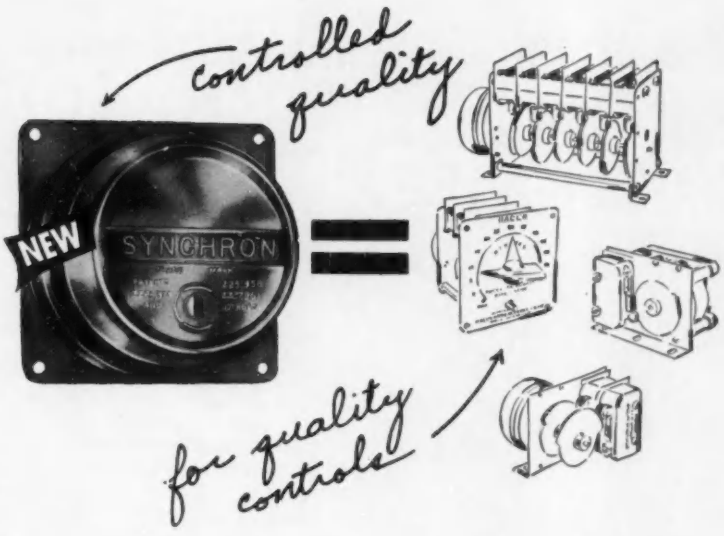
▶ Two divisions of Ampex Corp., Audio and Instrumentation, have displayed such growth and specialization that one Service Engineering Dept. no longer is capable of serving them. Accordingly, the department has been divided into two groups, an Instrumentation Group managed by **H. Van Childs,** formerly manager of the old department, and Audio Group, managed by **Kenneth R. Hall.**

▶ **Walt Edwards** and **Ed Klein,** formerly on the design engineering staff of National Cash Register Co.'s Hawthorne Laboratory, have been named chief systems engineer and project engineer, respectively, at NCR's Electronics Div. in Hawthorne, Calif.

▶ Among recent acquisitions: **Mountain Systems, Inc.,** of Thornwood, N. Y. (specialized business-data equipment) by **Airborne Instruments Laboratory, Inc.; Grove Valve & Regulator Co.** and **Grove Controls, Inc.,** both of Oakland, Calif. (controls and high-pressure regulators for the oil, gas, and chemical industries) by **Walworth Co.; Heli-Coil Corp.** of Danbury, Conn. (patented thread inserts) by **Topp Industries, Inc.** (CtE, Oct., p. 157), and **Acro Mfg. Co.** of Columbus, Ohio (electric switches and heating controls) by **Robertshaw-Fulton Controls Co.**

▶ And a merger: **Computer-Measure-**

(Continued on page 208)



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Engineered, constructed, and tested for durability! Depend on Synchron. Fine workmanship builds every Synchron Timing Motor. 51 individual tests and inspections before shipment guarantee top performance. Made to power your control designs according to your specifications. Always depend on Synchron Quality!

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***The HFG-1B or HFG-2 Heat-Flow Monitors using the disks are designed for this function.**

FREE: Illustrated data bulletin.

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ABSTRACTS

Two-Direction Pickup

From "An Air-Flow-Direction Pickup Suitable for Telemetering Use on Pilotless Aircraft" by W. L. Ikard, National Advisory Committee for Aeronautics. NACA Technical Note 3799, October 1956.

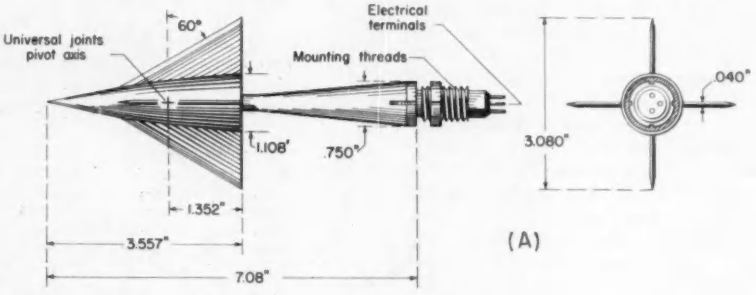
"In the determination of many aerodynamic parameters of aircraft in free flight, it is necessary to know the attitude of the airframe with respect to relative wind. Various instruments have been used on piloted aircraft to measure flow direction, but these instruments are generally unsuitable for use on high-speed pilotless-aircraft because of their large size or their inability to withstand the large accelerations and aerodynamic loads which are encountered."

This latest Technical Note on the subject describes the results of a project undertaken by NACA to meet its needs for a suitable dual air-flow-direction pickup. It covers the instrument's design requirements, its development and tests, and its aerodynamics, mechanical, and electrical performance. "In use, the dual-flow-direction pickup . . . has provided satisfactory data for pilotless aircraft operating at Mach numbers from 0.5 to 2.8 and dynamic pressures up to 65 psi."

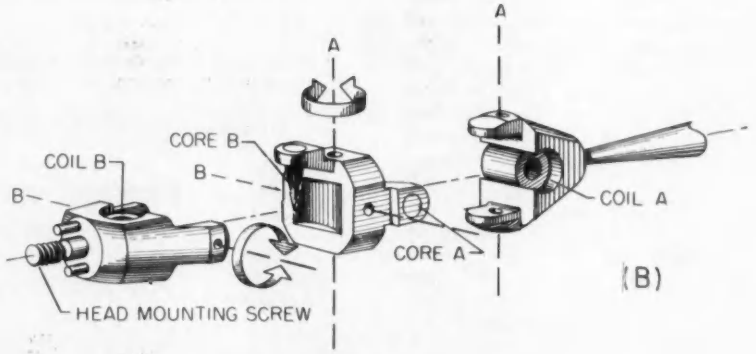
In brief, the pickup was required to have an absolute accuracy of at least 0.2 deg, a resolution of 0.1 deg under 20-g acceleration loads, and a permanent calibration of up to 75 g. Also, it was required to perform in this manner under maneuvers up to 15 cps. Separate electrical outputs from inductance pickoffs, which were proportional to the local angle of attack and angle of sideslip, were to be provided to operate into the NACA FM-AM telemetering system for use in the 100-to-200 kcps band.

After investigating several designs, the vane-type system of measurement was chosen. Figure A shows the external configuration finally adapted after wind tunnel test, Figure B the universal joint configuration (exploded view) providing for the dual-direction electrical outputs.

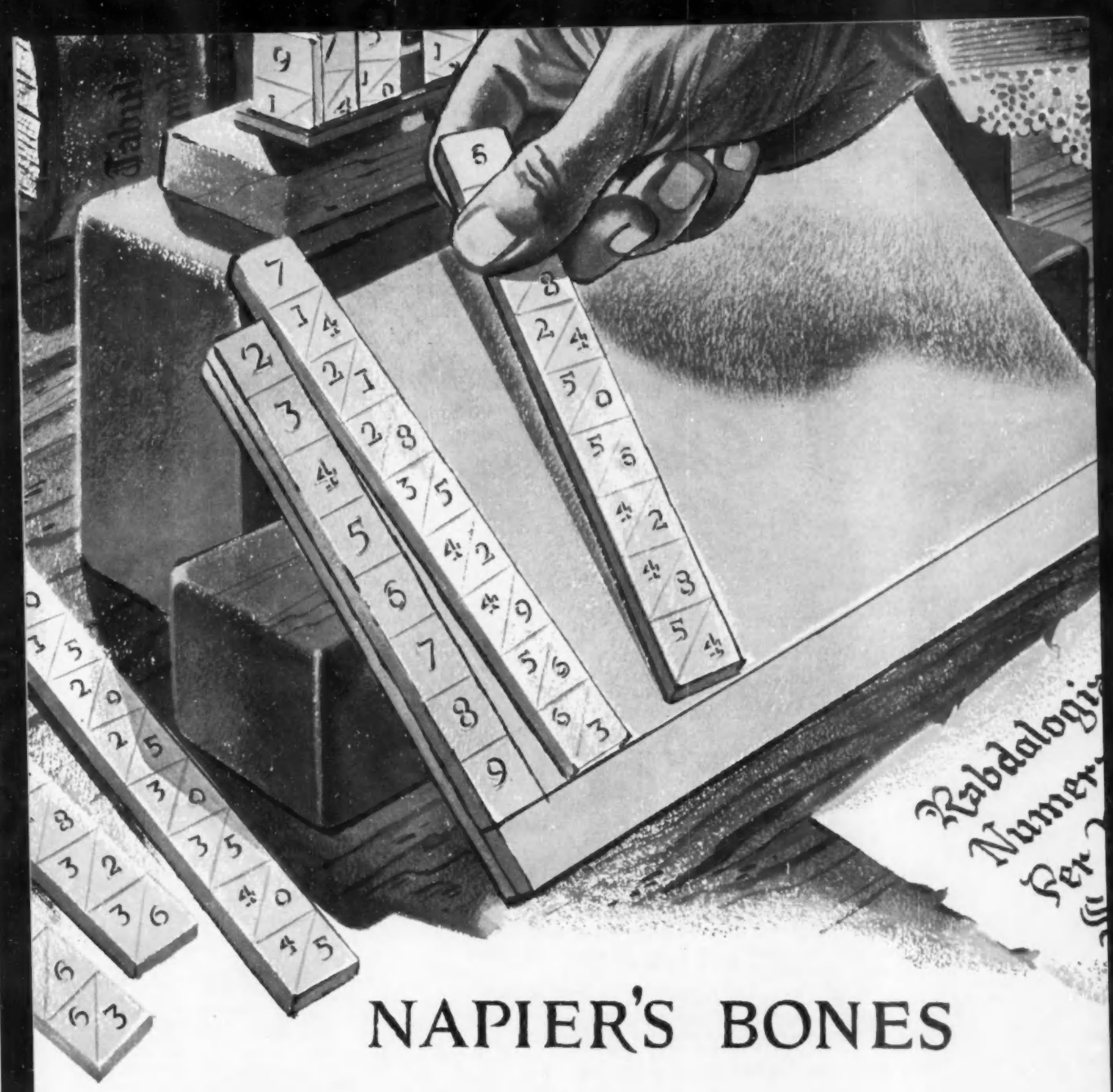
The dynamic response of the instrument was obtained during transient tests at various Mach numbers and various altitudes in a wind tunnel. The resulting curves of natural frequency of oscillation indicated the need for



External configuration.



Universal joint configuration, exploded view.



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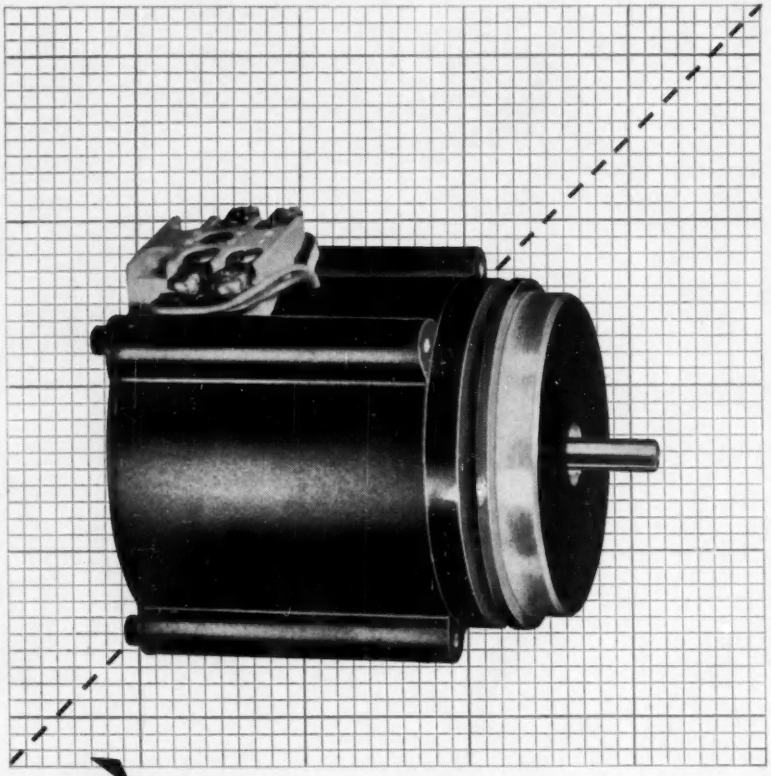
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This tachometer can be furnished separately as shown or mounted integrally with an A.C. Servomotor. Temperature compensated units are also available.

Note these specifications:—

Input	115 volts, 60 cycles
Output	6.0 volts per 1000 RPM
Linearity	± 0.5% above 1000 RPM and ± 0.25% between 50 & 1000 RPM
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A similar unit has been developed for 400 cycle operation.

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CE 357

Booth 2237—1957 Radio Engineering Show, New York Coliseum, March 18-21

ABSTRACTS

additional damping (high-viscosity silicone fluid) in the essentially frictionless bearings to retain reasonable damping at high altitudes.

The instrument yields an accuracy better than 0.2 deg. Its overall length is 7 in., the frontal area is approximately 1 in.², and the total weight is 0.32 lb. Pickup inductance varies 1.5 percent per degree of angle. Finally, "calibration [using a protractor] is direct and simple and the construction costs are relatively low."

Signal Stabilizing

From "Signal Stabilization of a Control System" by Prof. Rufus Oldenburger, Purdue University. ASME paper 56-A-92 contributed by the Instruments & Regulators Div. at the ASME Annual Meeting, New York, November 1956.

Oldenburger presents a simple, easily-implemented procedure for stabilizing hunting control systems. Essentially, his method is to inject into the moderately hunting system (not to exceed 10 percent of the full range of the controlled variable) a high-frequency large-amplitude signal. This reduces hunt amplitude substantially, and may possibly reduce it to zero.

Figure 1 shows the block diagram of a system employing signal stabiliza-

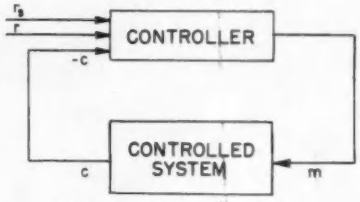


FIG. 1. System with controller.

tion, where r_s is the stabilizing signal, r is the reference value of the controlled variable, and c is the output of the controlled system.

This stabilization technique applies to linear systems controlled by linear functions; each system must have two or more lags, no lag dominating any other. The output, however, is bounded or limited, Figure 2.

For stabilization signal r_s to be effective:

- its frequency must be ten or more times greater than the hunt frequency f
- its amplitude must be greater (for example, 1.2 to 4, but not 20) than the value required for the output member to reach its output limit

"For a system with a linear-control

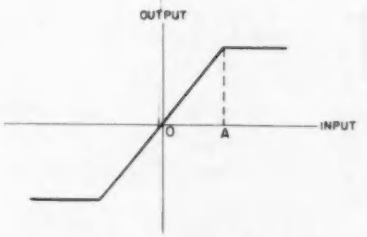


FIG. 2. Curve of bounded element.

function the stabilizing signal r_s may be introduced anywhere in the controller ahead of the output. In place of a sinusoidal signal, random noise may be employed. Also r_s can be taken to be a triangular wave, pulse, or other appropriate repetitive signal, with a frequency greater than or equal to $10f$ . . ."

Because the output is limited, the system's describing function gain decreases (see "Nonlinearity in Control Systems—Part II: Methods of Analysis and Synthesis" by R. J. Kochenburger, CtE, March 1956) as the input amplitude increases into the bounded region, point A, Figure 2. "The introduction of signal stabilization reduces the gains of the proportional and derivative channels, which both feed the bounding element, improving system stability accordingly."

The paper concludes with a description and curves of experimental tests of this technique, where a governor-engine system was simulated on a Philbrick computer.

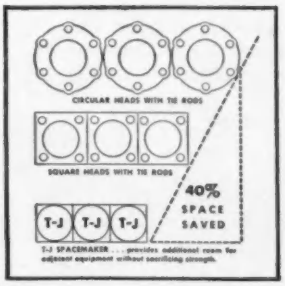
Wind-Tunnel Data Systems

From "Automatic Indicating and Recording Data Systems for Wind Tunnels" by J. B. D'Andrea, Wright Air Development Center. Report 16, Advisory Group for Aeronautical Research & Development, North Atlantic Treaty Organization, February 1956. Report available (in USA) from National Advisory Committee for Aeronautics, 1512 H Street, Washington 25, D. C.

This report, presented at the Eighth Meeting of the Wind Tunnel & Model Testing Panel February '56 in Rome, Italy, details the development, under D'Andrea's supervision, of a data reduction system for testing models in wind tunnels. The project started in 1949 and by March, 1952 the unit was operative. In December 1955 a new strain gage console was installed to replace the original one. Even before its installation, however, the reduction system:

- ▶ increased wind tunnel productivity from ten to (a planned objective of) 25 tests per year
- ▶ expedited test of priority projects

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ABSTRACTS

► improved accessibility of raw data for further reduction

► saved 40 man-hours per operational shift

► reduced cost of data reduction by approximately $350,000 per year

The author first describes the general arrangement of the instrumentation and data recording equipment in the WADC 10-ft transonic wind tunnel. "The forces and moments acting on the model, due to the air flow, are transmitted to the strain gage balance, which in turn converts these data to electrical signals. The millivolt signals are fed to self-balancing potentiometers and, by utilization of shaft analog-to-digital converters, are translated to digital outputs. These outputs are then presented to the Card Punch, Tabulator and Plotter for recording."

The operating sequence for this equipment, following initiation of a test signal, is:

- deenergizing one phase of the drive motors in the self-balancing potentiometers to "freeze" all active servos, thus preventing any spurious signals from upsetting instrument readings
- energizing the rotary solenoids that align and close the contacts of the digital converter
- reading out digital information on the card punch and punching the data onto cards; and simultaneously photographing manometers and taking schlieren photographs
- reading out digital information on the tabulator, printing the data on paper, and storing pertinent data in counters
- allowing the rotary solenoid and the self-balancing potentiometer to assume new balance positions due to any change in model attitude or tunnel conditions
- reading out stored information in the tabulator and plotting this on the plotter, yielding from one to eight different data components

The first five steps enumerated above take about 3 sec, while the last step takes up to 17 sec for the eight points. "Hence, at the completion of the plotting cycle, the data recording system is again ready for a new cycle. The maximum time needed between recording of data at different test points is approximately twenty seconds."

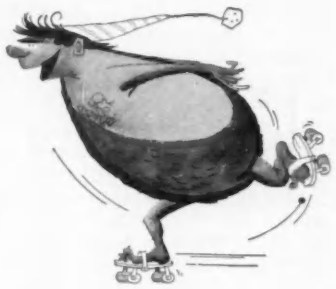
The second part of the report describes the major pieces of equipment and their integration into a compatible data reduction system. The data converter consists of a standard extended-

range self-balancing potentiometer operating from the strain gages in the wind tunnel and an electromechanical shaft analog-to-digital converter connected to the potentiometer's drive motor by a series of spur gears. "The gear train is such that a zero to three millivolt dial movement of the potentiometer causes the input shaft of the digital converter to rotate 120 revolutions, yielding 1200 counts."

Another important unit described by D'Andrea is the damping device. This equipment smooths oscillating signals obtained from the strain gages when (under certain conditions) the model and strain gage balance vibrate. Since the balancing servos are stopped when a reading is taken, it is quite likely that, without smoothing or averaging, they would be stopped at an extreme value and lead to erroneous data. Because the damping arrangement makes the response sluggish, provision is made to have the damping effective only near balance.

The final section of this report describes the interconnections of the card punch, tabulator, and plotter. Pertinent test data are stored, in a modified standard tabulator, in 14 four-digit counters and four six-digit counters. The information is then systematically read out of the counters

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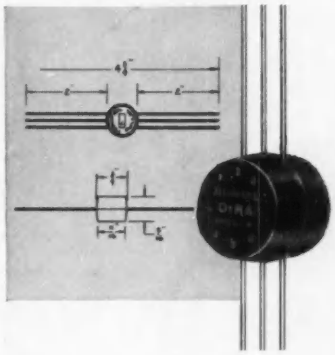
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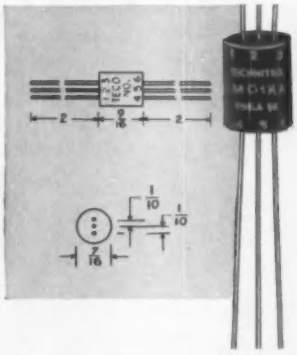
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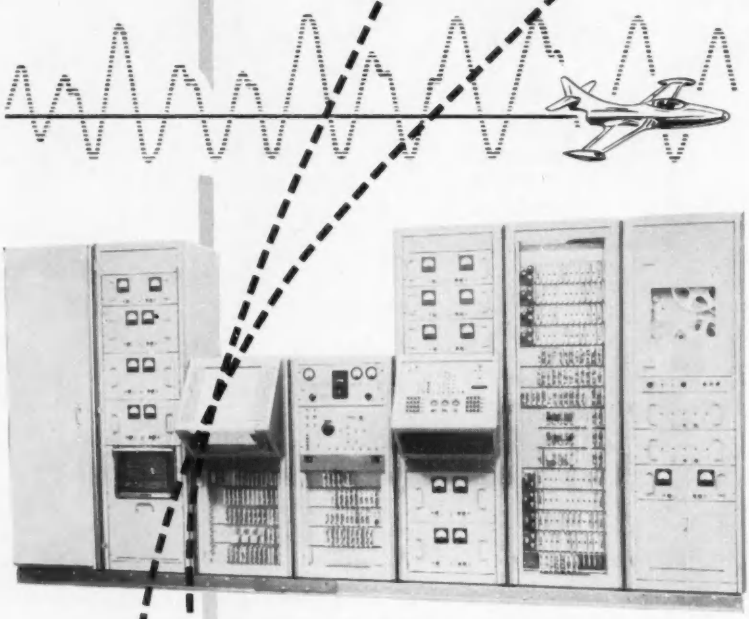
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as X and Y values and plotted as eight points (maximum) on eight different curves. Then, after completion of another test point in the wind tunnel, eight more points are plotted on the eight curves, and so on. During the programming of the tabulator and plotter, constants are added to offset the eight curves. Negative-valued test data can be handled by storing the information in the counters as complements.

NACA Progress

From the "Forty-Second Annual Report of the National Advisory Committee for Aeronautics." Headquarters, 1512 H Street NW., Washington 25, D. C.

The following material on NACA's activities in the fields of automatic stabilization and control has been excerpted verbatim from its Administrative report to Congress. Ed.

The problem of determining the differential equations governing the behavior of a dynamical system, given a time history of the response of the system to some input, has been of interest to aerodynamicists for some years. A general theory for the analysis of dynamical systems has been developed at the Ames Laboratory ("equations-of-motion" method). This theory was presented at the Conference on Nonlinear Control Systems conducted jointly by the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. It was noted that, when looked at from a new point of view, all such methods can be generalized so as to apply to linear and nonlinear systems alike. Use of this theory also has shown how new methods can be developed to satisfy the requirements of particular problems. One method developed has certain advantages over methods heretofore used. Its superiority is based on two facts: (1) The heavy dependence on the initial conditions which occur when using most of the previously known equations-of-motion methods is eliminated, and (2) there is no need for infinitely long records of the motions of the system following a disturbance. Finally, the time of application of the new method is no greater than that for existing methods and it is well suited to machine computation.

* * *

As a result of the present interest in the spiral-stability problem asso-

ciated with most personal-owner airplanes, the Flight Research Division of the Langley Laboratory has undertaken a program to investigate the effectiveness of a spiral-stability augmenting device. The specific problem facing the pilot of a personal-owner airplane is to maintain his airplane in wings-level flight during times when he has no natural-horizon reference and to keep the airplane from diverging spirally while he may be preoccupied with navigational problems. It has been demonstrated that the pilot's sense of orientation is unreliable in the absence of a visual reference, as may be the case when inadvertently or unavoidably encountering instrument weather. Also, many personal airplanes are equipped with only the basic instruments for instrument flight (turn indicator, ball-bank indicator, altimeter, and airspeed meter). Considerable proficiency in instrument flying is required to interpret the indications of these instruments properly and, in many cases, personal-airplane pilots are not sufficiently skilled in instrument flying to undertake it with safety. Although most present-day personal-owner airplanes, particularly those with high-wing designs, possess a slight degree of inherent spiral stability in cruising

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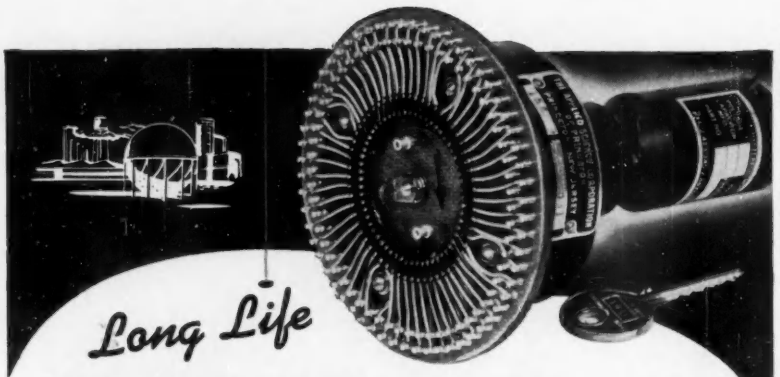


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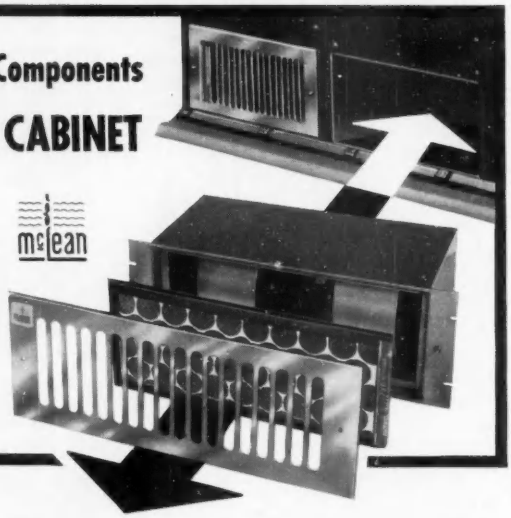
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ABSTRACTS

flight, they show unstable spiral tendencies under operational conditions. The main reasons for this apparent spiral instability are a lack of means for trimming the airplane laterally or directionally, a variation of lateral and directional trim with airspeed, and control-system friction which prevents the control surfaces from returning to trim position after a control deflection, even if there had been a means for initially trimming the airplane.

The device studied utilizes a rate-gyro sensing element to switch the control effort of an on-off type of control. This control deflects the ailerons at a constant rate relative to a spring preloaded aileron neutral position. An analytical study using phase-plane and analog-computer methods was carried out to determine a desirable control-effort switching function for the on-off or nonlinear control used in this device. Results of the analytical study indicate that the nonlinear control is effective in compensating for directional trim changes of the airplane due to changing flight conditions and also in rapidly returning the airplane to level flight from an initial roll displacement. Results of the flight-test program reported in Technical Note 3637 essentially verified the analytical results; that is, the device is capable of maintaining the airplane in equilibrium over its operational speed range under directional out-of-trim conditions that would cause rapid divergence of the normal airplane. The device also prevents excessive heading wander and airplane gyrations in turbulent air without pilot control. A means for holding the airplane in a stabilized turn to facilitate mild maneuvering through use of the automatic control is provided.

As part of a general research program for testing various means of automatic stabilization, the Pilotless Aircraft Research Division of the Langley Aeronautical Laboratory has been conducting an investigation of various autopilot systems, including both linear and nonlinear systems. Nonlinear control systems have been considered as an effective, and possibly a simple way, of obtaining desired missile responses automatically. One such system, using a mechanical linkage with a dead or inoperative region as a means of providing an effective rate signal in an autopilot, has been studied in laboratory tests and through calculations of resulting missile motions in roll. Thus, a mechanical de-

vice is used to improve system performance in a manner similar to that which would be obtained by using a rate gyroscope. Laboratory tests of an actual servo using this device in connection with an electro-mechanical simulator of the rolling motion of a missile show the conditions under which a higher degree of stability is obtained with this nonlinear arrangement than with that of a comparable linear system. Results of this study are given in Technical Note 3602.

Briefly Noted

Automatic Data Reduction, Part II. A Catalog of Devices Useful in Automatic Data Reduction. R. S. Hollerith and A. K. Hawkes, Armour Research Foundation for Wright Air Development Center, November 1954, 80 pages. (Order PB 111928 from OTS, U. S. Dept. of Commerce, Washington 25. Price $2.00).

The catalog lists equipment commercially available for automatic data recording and reduction systems, and similar devices under development. Essentially digital in nature, the items are separated into five categories: analog-voltage-to-digital converters,

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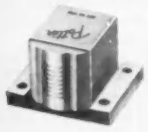
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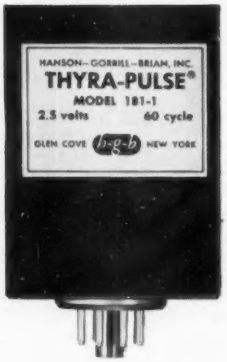
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ABSTRACTS

shaft-position-to-digital converters, digital plotters and digital-to-analog converters, miscellaneous digital devices, and special tape recorders. Included are model, type, size, manufacturer, operating procedure, range, power, and available modifications for each device shown.

WHAT'S NEW

(Continued from page 197)

ment Corp. with **Hancock Mfg. Co.** of Jackson, Mich.

Heidelberg Resolution Spurs Ideas for New Association

Working within the framework of the Heidelberg resolution calling for an international federation of control engineering and automatics, delegates of accredited control engineering associations already existing in countries which are neighbors of France met in Paris on Dec. 18 and 19. Under the chairmanship of Professor Veron, president of the French Association for Control Engineering and Automatics (AFRA), the following delegates convened in the Assembly Hall of the National Conservatory for Arts and Trades:

Messrs. Ruppel, secretary general of the Provisional Committee for Control Engineering and Automatics, and Frank (VDI/VDE Fachgruppe Regelungstechnik, Germany)

Professor Hoffmann (vice-chairman of the "Institut Belge de Régulation et d'Automatisme")

Mr. Bertini and Professor Giornelli (Consiglio Nazionale delle Richerche and Associazione Nazionale Italiana per l'Automazione)

Mr. Lindenhovius (chairman of the Royal Netherlands Engineering Institute's Group on Automatic Control Engineering)

Mr. Ambrosini (Swiss Association for Automatics)

Messrs. Broida, Lehman, Loeb, and Wilfart (France)

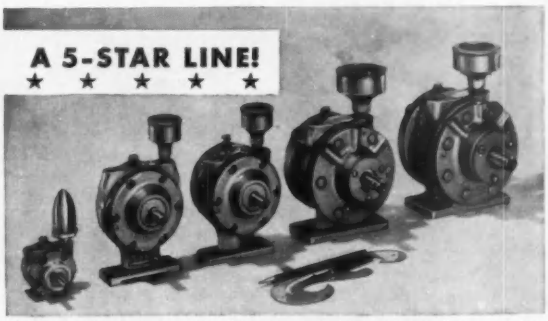
The Belgian, Dutch, French, German, Italian, and Swiss representatives recognized two possible structures for the international federation, which they decided to call "The International Federation of Applied Automatics":

▶A federation with relatively limited aims, reduced mainly to the sponsorship of international conventions in the field of automatics and to the exchange of general technical information between the member countries.

This is the formula advanced by the Heidelberg resolution and favored by a majority of Americans who now form a North American Committee under the leadership of Professor Oldenburger, American member of the Provisional International Committee.

►A federation with a wider purpose and a more organized structure, which would truly coordinate, on an international level, the development of theoretical and applied automatics, as well as progress in research work, information and documentation activities, and studies of technical problems in automatics conducted separately in the various member countries. This formula is advocated in several other countries and is reflected in the draft of rules prepared by Mr. Broida as chairman of the Provisional International Committee and submitted by him to Chairman Véron and to the other members of the same committee.

Recognizing that it could not reasonably take a stand on the substance of the problem—since only six countries were represented at this meeting, out of the 18 which had signed the Heidelberg resolution—the conference moved on to the study of the rules drafted for the future international federation. This draft was prepared



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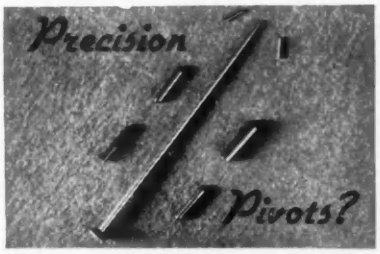
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4 AM	1,000 2,000	0.48 0.78	0.73 1.10	7½
6 AM	500 2,000	0.40 1.30	0.65 2.00	18
8 AM	500 1,500	1.00 2.30	1.45 3.80	25

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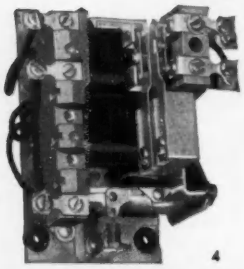
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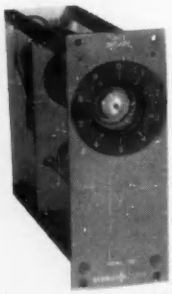
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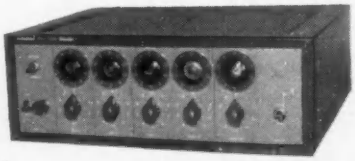
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WHAT'S NEW

by Mr. Broida and corresponds to the second solution. The draft—amended in accordance with pertinent suggestions made by Mr. Ruppel (Germany) and Professor Hoffmann (Belgium)—was then forwarded to all the signatories of the Heidelberg resolution and to the associations specializing in applied automatics, wherever such associations already exist.

The conference also asked Professor Oldenburger (U.S.A.) to forward to the same addressees a different set of draft rules corresponding to the first solution, which seems to be preferred in America. This procedure will allow each country independently and objectively to indicate the solution of its choice.

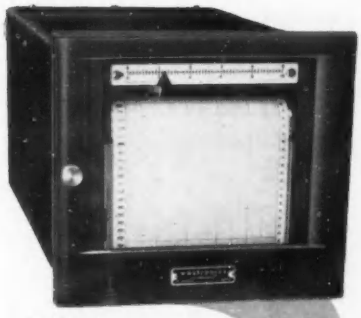
The conference then examined problems relating to the coordination and unification of classification methods for technical information on automatics, of terminology in that field and of connections in functional schematics (block-diagrams) in frequent use by control engineers. It was noted in this respect that highly-qualified organizations such as the International Federation of Documentation (regarding decimal classification of general information material) and the International Electrotechnical Commission (regarding terminology and functional schematics) were already studying these problems. Therefore, the activities of the national associations of automatics (and of the future International Federation of Applied Automatics) should avoid duplicating the work of those organizations, but should endeavor to assist them by furnishing specialists in the field of automatics.

The provisional committee will establish liaison—in the three areas of document classification, terminology and functional connections—with the international organizations already active in these particular fields. This liaison will enable the International Federation of Applied Automatics to obtain an overall view of these matters and possibly also to offer these organizations some constructive suggestions.

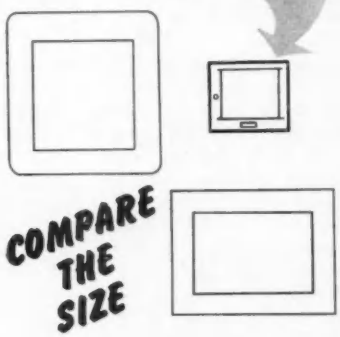
The Provisional International Committee will also gather information on the various standards in the field of automatics, containing definitions and a theory terminology in use in several countries (Germany, Great Britain, the U.S.A., the Netherlands and Switzerland), so as to familiarize itself with these questions and pass on its knowledge to the national associations.

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NEW BOOKS

Foreign-language booksellers

From time to time our readers request the names and addresses of dealers from whom they can purchase the books, particularly the foreign-language books, reviewed in these columns. This month CtE devotes part of the New Books section to a list of the most-likely booksellers. The list was prepared by Prof. T. J. Higgins, whose reviews of foreign-language books appear frequently in this space. Ed.

EAST COAST

Four Continents Book Corp., 55 West 56th St., New York, deals only in Russian texts. Supplies books in any technical field, though it is limited, of course, by what is available for sale.

Stechert-Hafner, Inc., 21 East 10th St., New York, supplies books in any language in any technical field.

Stevens & Co., 1841 Broadway, Room 201, New York 23, supplies texts in any language in any field, and seems to have a good supply of Russian books.

Charles Tuttle Co., Rutland 9, Vt., the primary source for Japanese books (many of which are printed in English) in this country. It maintains a branch in Tokyo and gets books directly.

MIDWEST

Brentano, 29 S. Wabash Ave., Chicago, Ill., maintains a fairly large stock of European books, mainly those published in England. No doubt it will process an order for any foreign-language book.

WEST COAST

There does not appear to be any bookseller on the west coast specializing in foreign technical books, but any reliable local bookseller probably will process an order.

England

W. Heffer & Sons, Ltd., ¾ Petty Cury, Cambridge.

Blackwell, Basil, & Mott, Ltd., 49 Broad St., Oxford.

Galloway & Porter, 30 Sidney St., Cambridge.

Henry Sotheran, 2, 3, 4 Sackville St., Piccadilly, London, W. 1, will take orders for any book in any lan-

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Automation Library

AUTOMATIC TECHNOLOGY AND ITS IMPLICATIONS: A SELECTED ANNOTATED BIBLIOGRAPHY. — *Bulletin No. 1198, United States Department of Labor,* August 1956. 78 pp. *Published by Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.* $.45.

This bibliography is intended to expedite use of the growing volume of published material on automatic technology and its social and economic effects. It should prove of interest to engineers concerned primarily with management and production, to university teachers and graduate students in industrial management, and to control engineers interested in problems connected with design or use of automatized production lines.

The 359 references are to periodical articles, books, reports, speeches, pamphlets, conference proceedings, and other readily available materials devoted to "operations of automated equipment in business and industry, analysis of the conditions for their use, and discussion of the implications for labor, management, government, and the economy".

These references are classified under 14 broad subdivisions: I. General surveys; II. Automation in metal working; III. Mechanized bulk materials handling; IV. Automatic production of electronic goods; V. Automatic control in processing; VI. Automatic control of machine tools; VII. Electronic computers — technological aspects; VIII. Electronic data processing in business offices; IX. Electronic data processing in science and engineering; X. Electronic data processing in industrial production; XI. Economic and social implications; XII. Union attitudes and policies; XIII. Implications for business organization and management; XIV. Bibliographies and glossaries. In addition, there are four appendixes: A. Index to authors; B. Index to subjects; C. Names and addresses of periodicals; and D. Names and addresses of publishing organizations. A random sampling indicates that the coverage is good and that the

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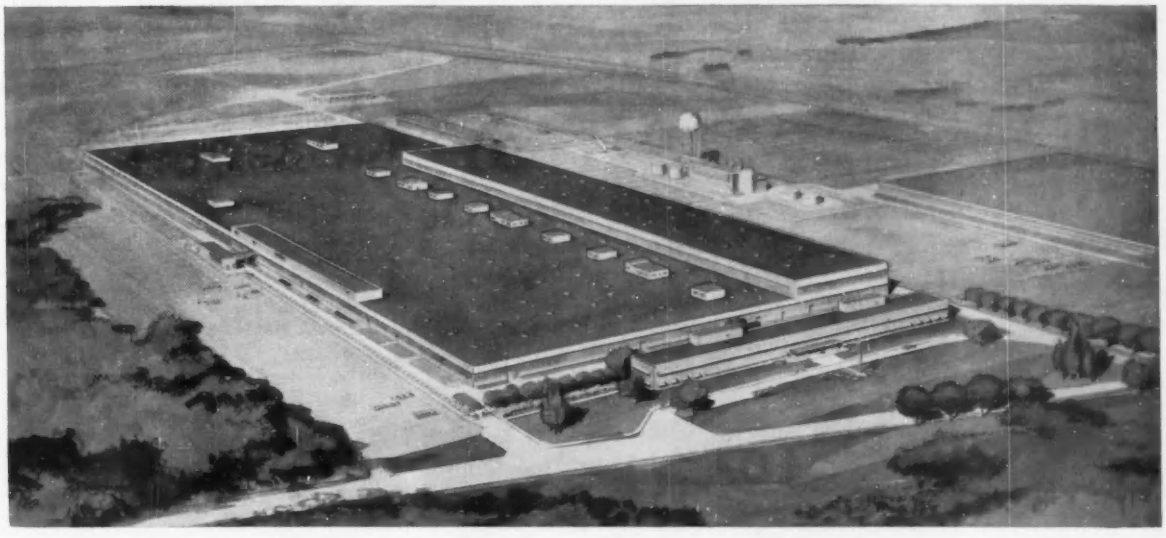
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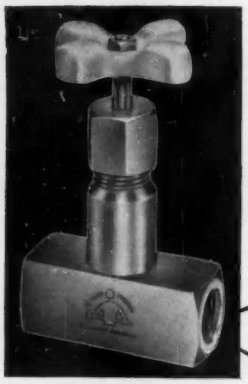
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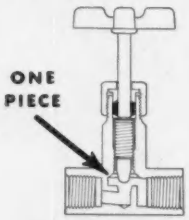


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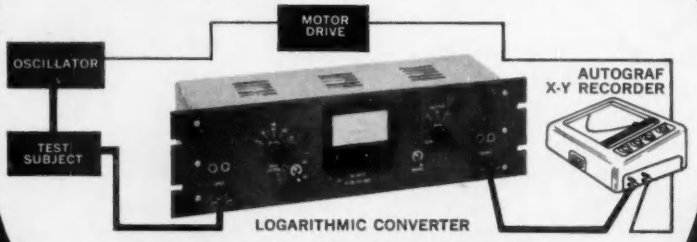
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brief annotations of the items provide a good idea of the essential theme.

Measurement Systems

INSTRUMENT ENGINEERING, VOL. III. APPLICATION OF THE INSTRUMENT ENGINEERING METHOD: PART I, MEASUREMENT SYSTEMS. *C. S. Draper, W. McKay, and S. Lees. Published by McGraw-Hill Book Company, Inc., New York.* $17.50.

This book, part of a continuous and exhaustive work on instrument engineering, follows *Methods for Describing the Situation of Instrument Engineering* (1952) and *Methods for Associating Mathematical Solutions with Common Forms*, (1953). Part II of the present book will be on feedback control systems. Because of the unique organization of the series, each book can be studied and used independently while adding to a knowledge about the subject.

Lecture notes on instrument analysis, from courses taught by Prof Draper and his colleagues, account for a large amount of the material in this third volume. Other material results from the consulting, experimental, and research work on instrumentation carried out at MIT over a considerable span of years.

Vol. III, Part I deals with the actual design of devices, thus keeping detailed mathematical analysis to a minimum. The authors present much ready-to-use data in the form of equations, charts, and curves. Self-defining symbols speed comprehension of the equations and discussions. The approach includes repeating some of the fundamentals contained in the previous volumes, resulting in an exhaustive reference text on measuring instruments and systems.

The first chapter describes the construction and functions of instruments and systems in terms of their component and block diagrams, equations of performance, definitions, notation, and terminology. The following chapters then get down to specifics of indication, measurement, and classes of instruments.

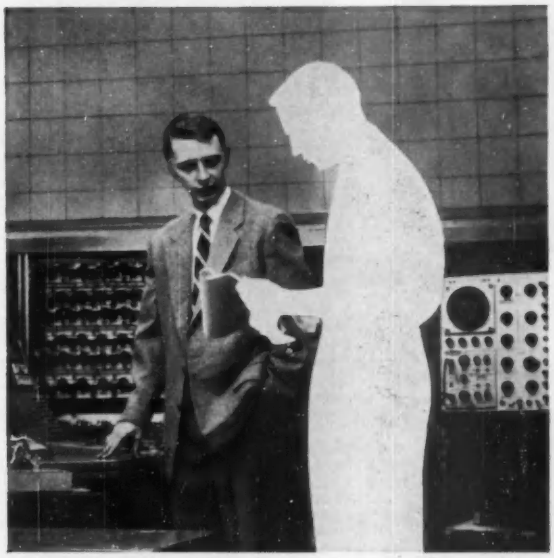
An instrument is considered in terms of input receiver, coupler, and indicating unit; each is discussed along the lines of calibration, accuracy, sensitivity, error, error analysis, and method of static and dynamic correction.

Coverage of temperature-measuring instruments embraces the principal features of the more commonly en-

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PRODUCT CONTROL ENGINEER: Promoted recently, this man formerly worked at IBM's Poughkeepsie manufacturing facilities. His job was to design information systems to insure a smooth flow of work through the plant. "It takes *creative* engineering ability to design these systems," he'll tell you, "and *administrative* ability to 'sell' a system to higher management and make it stick. If you possess this rare combination of abilities, this is the job for you!"

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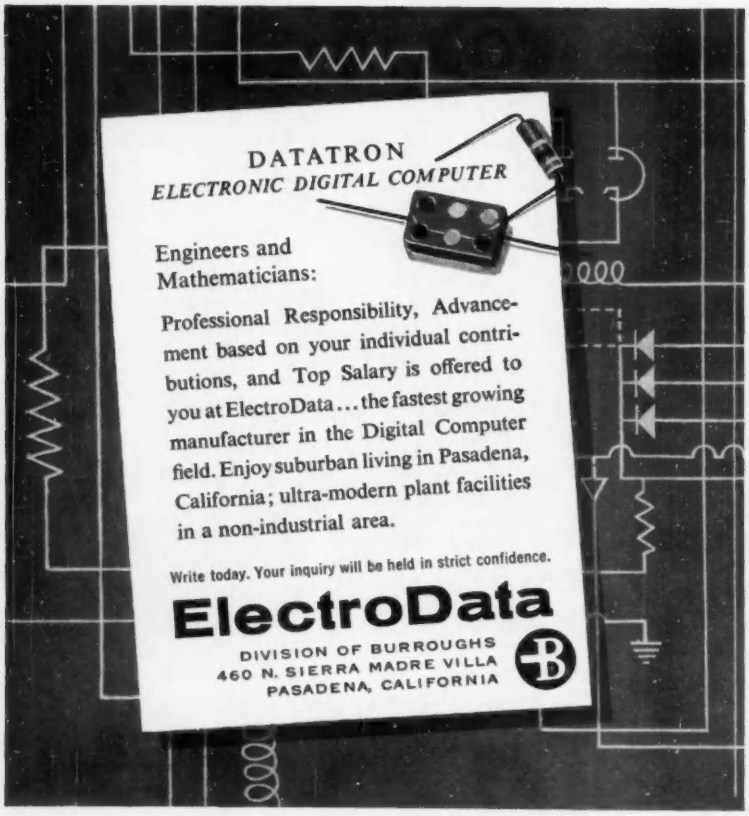
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countered devices, and their responses to step, ramp, and sinusoidal inputs, and their other performance characteristics are determined.

Electromechanical measuring instruments come in for thorough treatment, too. A study is made of, for example, moving coil and moving iron instruments, with particular reference to damping qualities, construction and performance characteristics, and tests for ascertaining responses. Pulse testing of mechanical oscillographs is also covered.

A section on pressure-measuring instruments parallels the coverage of temperature-measuring instruments.

Also treated are integrators and differentiators and the use of electronic computers in the solution of simple differential equations. Integrators discussed include: ball and disc, watthour meter, viscous-damped, liquid-flow, thermic, and pneumatic-pressure devices, and RC and other electrical networks. Discussion on differentiation covers electrical networks, feedback amplifiers, and tachometers.

The last chapter deals with vibration measurement of one-, two-, and three-degrees-of-freedom systems, and vibration isolation of single-degree-of-freedom systems.

A Mathematician Reflects

I AM A MATHEMATICIAN. *Norbert Wiener, professor of mathematics, MIT. 380 pp. Published by Doubleday & Co., Inc., Garden City, New York, 1956. $5.00.*

This is the second part of the autobiography of one of the most distinguished American mathematicians. The first part, *Ex-Prodigy*, covered his childhood, youth, and young manhood—to the age of 24—and concluded with his appointment in 1919 as an instructor at MIT. The present part continues the saga to his present age of 60-plus.

Ex-Prodigy (Simon and Schuster, New York, 1953, $3.95) centered attention largely on Wiener's education, his relations with his parents, and the unusual experiences of an infant prodigy. The most important influence of his childhood and adolescence, his father, Leo Wiener, was a strong-minded, largely self-educated man who, after emigrating to this country, conjoined an indomitable will, a herculean capacity for work, and exceptional linguistic capacities to gain eventually a professorship of Slavic languages and literatures at

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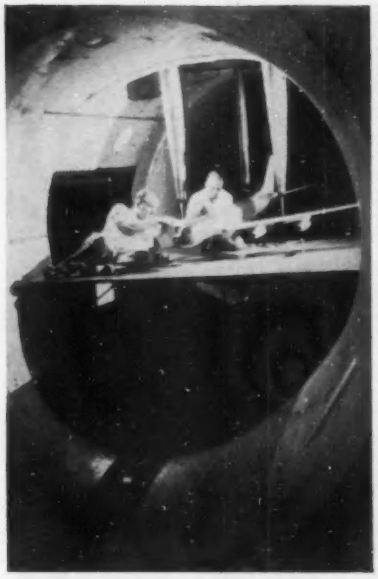
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NEW BOOKS

Harvard. In university, home, and social circumstances that were quite different from that of the usual American lad, Wiener passed most of his first score of years—with a year's interval for graduate work at Cornell. The experiences that followed are discussed frankly and in detail: study at Tufts (where Wiener took his bachelor's degree at 14), at Cornell, and at Harvard (which awarded him a PhD at 19); postgraduate work at Cambridge University in England and at Göttingen in Germany; lecturing at Harvard and teaching at the University of Maine; work at Lynn for the General Electric Co. and hack-writing in Albany for the Encyclopedia Americana; ballistic computation at the Aberdeen Proving Grounds as a civilian, and then a soldier, during World War I; and, finally, an appointment at MIT. Interwoven with this record of personal development and educational training are outspoken accounts of those (parents, friends, and teachers) who influenced, aided or opposed him, how and why they did so, and their effect on his life.

The emphasis on this second volume of his life is on Wiener's development and career as a working mathematician, and on his social and professional relationships with mathematical colleagues all over the world. High-spots are the trip to the International Mathematical Congress of 1920 at Strasbourg, the years of intellectual consolidation during 1920-1925, travel abroad in the summers of these years, during which he worked on the quantum theory with Born at Göttingen; marriage and work at Göttingen and Copenhagen during 1926-27 as a Guggenheim fellow; years of growth and progress during 1927-31; residence at Cambridge University during 1931-32; a decade of teaching—and later—war work at MIT, with a year interlude partly devoted to teaching in China during 1935-36; and trips to Mexico City in 1944, to Nancy and Paris in 1946 (which initiated the books on Cybernetics, and *The Human Use of Human Beings*), and to India in 1953; and—finally—subsequent work at MIT and on the two-part autobiography.

The engineer will find of especial interest Wiener's accounts of his work on the early versions of the differential analyzer and optical integraph (with Bush); on the possibilities of high-speed computing devices for partial differential equations; on filter theory



If production "pivots" on costs

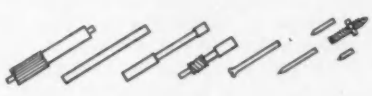
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and the foundations of the statistical theory of noise-signal transmission (with Y. W. Lee); on certain integral equations that are of use in study of certain phases of the theory of prediction and of filtering (with Hopf); on prediction theory, feedback studies, computers and associated apparatus development during the war (with Julian Bigelow); on physiological and anatomic studies in human cybernetics (with Rosenblueth); and on the origins and course of publication of his three books on "time series, extrapolation and interpolation, on cybernetics, and on automation and its human aspects".

The two-volume work ranks among the half-dozen most interesting of the some 2,000 biographies and autobiographies in English of eminent scientists and technologists the reviewer has read.

NOTE: For a detailed bibliography listing the some 2,000 works noted above, see T. J. Higgins, "Book-Length Biographies of Engineers, Metallurgists, and Industrialists", *Bulletin of Bibliography*, Vol. 18, 1946, pp. 206-210; 235-239, and Vol. 19, 1947, pp. 10-12. Copies are available gratis from the Director, Engineering Experiment Station, Mechanical Engineering Building, University of Wisconsin, Madison, Wis.

Analyzing by Numbers

NUMERICAL ANALYSIS: WITH EMPHASIS ON THE APPLICATION OF NUMERICAL TECHNIQUES TO PROBLEMS OF INFINITESIMAL CALCULUS IN SINGLE VARIABLE. *Zdnek Kopal, professor of astronomy, University of Manchester.* 556 *pp. Published by John Wiley & Sons, Inc., New York.* $12.00.

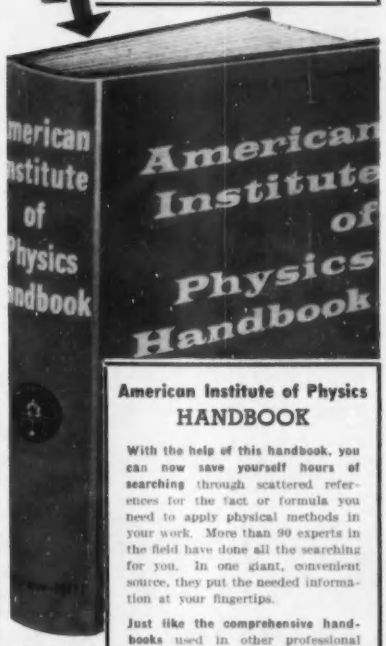
The aim of this book is "to develop, in a systematic manner, the analytical basis of such numerical processes as are necessary for an algebraization and numerical solution of a wide range of problems of the infinitesimal calculus which are encountered daily in physics or engineering, but are not amenable to solution by formal mathematical methods".

Rather than such familiar topics in "numerical analysis" as solution of high-order algebraic and transcendental equations, sets of linear or non-linear simultaneous equations, or partial differential equations, the book concentrates on the one-variable calculus, especially the solution of problems in physics and engineering not amenable to solution by exact analytic procedures.

A short Chapter I traces the historical evolution of numerical analy-

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NEW BOOKS

sis, emphasizing its growing importance as automatic digital computers become more common, and stresses the necessity of at least a basic knowledge of numerical analysis. Chapter II develops interpolation formulas on which are based the various procedures derived in Chapter III, on numerical differentiation, and Chapter IV, on integration of ordinary differential equations.

The next two chapters are largely unparalleled in other English language texts. These unique chapters encompass a very interesting and useful account of two major procedures for the numerical solution of boundary-value problems: Chapter V deals with algebraic methods, and Chapter VI with variational, iterative, and other methods. The Royleigh-Ritz and Schwarz methods are especially well delineated.

Chapter VII describes Gaussian and closely associated methods of approximating the definite integral of a function by a properly weighted sum of particular values of the integrand. These procedures are then applied in Chapter VIII, which covers numerical solution of integral and integro-differential equations, another area not too well-covered in English language books and of considerable importance in analyzing control structures of such modern devices as nuclear reactors.

Five appendixes discuss operational procedures for infinite difference analysis; trigonometric interpolation, including use of Tchebyshelf polynomials; a table of coefficients of the Lagrangian formulas for numerical differentiation; numerous tables facilitating mechanical quadrature; and selected references to sources on solution of polynomial and simultaneous linear equations.

Each chapter, except for the first, is followed by helpful bibliographical notes containing references and constructive critical and chronological comments and a set of simple and difficult problems for student practice and research theses.

The book, which originated as a series of lectures by the author at MIT between 1947-51, is particularly suited as a textbook for senior or graduate students in mathematics, the physical sciences, and engineering. It can also be read by the control and/or computer engineer who wishes to bring his knowledge of numerical analysis up to date.

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Here members of the Electronics Division discuss systems radar problems related to measurement of missile trajectories. Left to right: K. T. Larkin, radar and command guidance; Dr. S. B. Batdorf, head of the Electronics Division; Dr. H. N. Leifer (standing), solid state; Dr. R. J. Burke, telemetering; S. Janken, product engineering.

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MISSILE SYSTEMS DIVISION

WHAT'S AHEAD: MEETINGS

FEBRUARY

Western Joint Computer Conference, Hotel Statler, Los Angeles Feb. 26-28

MARCH

American Society of Mechanical Engineers, Nuclear Congress, Convention Hall, Philadelphia March 10-16

Institute of Radio Engineers, 1957 National Convention and Exhibition, N. Y. Coliseum and Hotel Waldorf-Astoria, New York. March 18-21

Nineteenth Annual American Power Conference, Hotel Sherman, Chicago March 27-29

APRIL

New Jersey Section of Instrument Society of America, Ninth Annual Symposium (subject: "Process Fluid Analyzers"), Hotel Essex House, Newark April 2

American Society of Mechanical Engineers, Spring Meeting, Dinkler-Tutwiler Hotel, Birmingham, Ala. April 8-10

Semicentennial Celebration, Pace College, New York City April 10

Instrument Society of America, National Nuclear Instrumentation Conference, and Third Southeastern Regional Exhibit, Atlanta Biltmore Hotel, Atlanta, Ga. April 10-12

Second National Simulation Conference, and Ninth Southwestern Institute of Radio Engineers Conference and Electronics Show, Shamrock Hotel, Houston, Texas April 11-13

American Society of Mechanical Engineers, Instruments & Regulators Div. (IRD) Third Annual Conference, Northwestern University, Evanston, Ill. April 22-24

Second National Industrial Research Conference, "Research for Profit", sponsored by Armour Research Foundation of Illinois Institute of Technology, Conrad Hilton Hotel, Chicago April 24-25

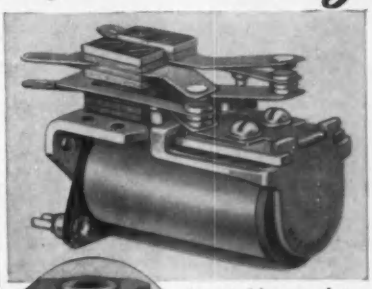
Seventh Region Institute of Radio Engineers Conference, Balboa Park, San Diego, Calif. April 24-26

MAY

Electronic Components Symposium (sponsors: AIEE, IRE, Radio-Electronics-Television Mfrs. Association, West Coast Electronic Mfrs. Association), Morrison Hotel, Chicago May 1-3

Fluid Control Institute, Greenbriar, White Sulphur Springs, W. Va. May 8-11

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- Draftsmen
- Electricians
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- Engineers — Civil
- Engineers — Electrical
- Engineers — Mechanical
- Engineers — Mining
- Fabrication Metal Products
- Fabrication of Textile Production
- Foremen Construction
- Furnacemen Smelters Pourers
- Loom Fixers
- Machine Shop
- Miners Mining Machine Operators
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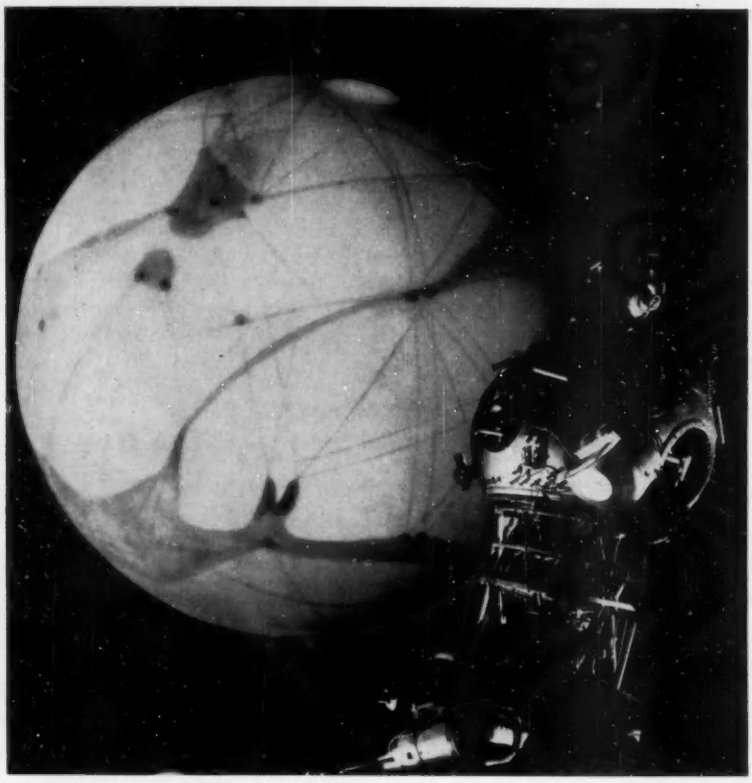
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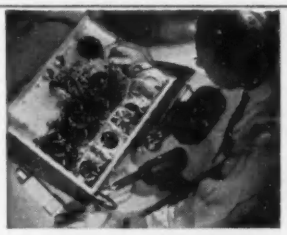
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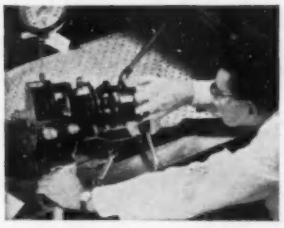
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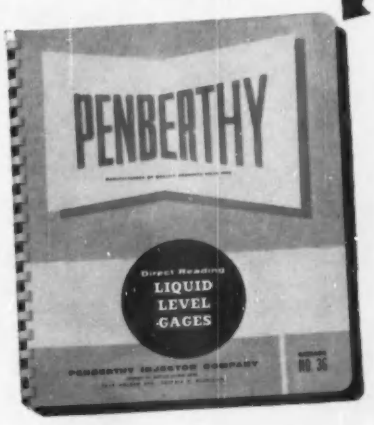
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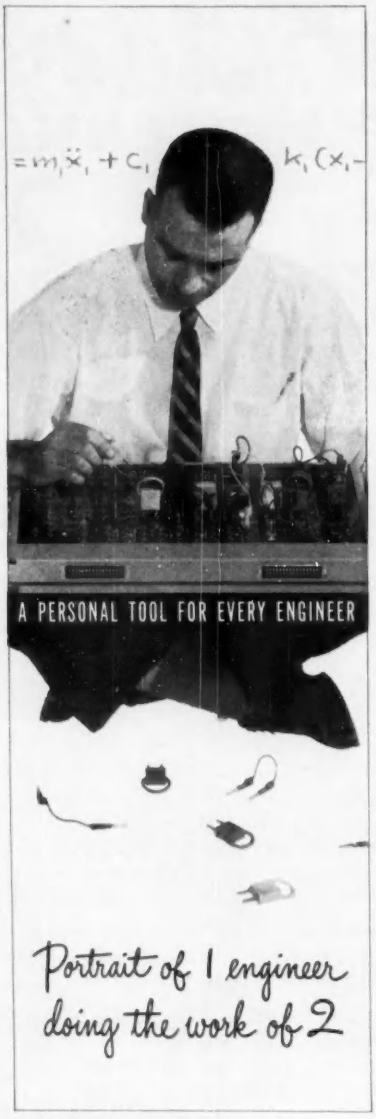
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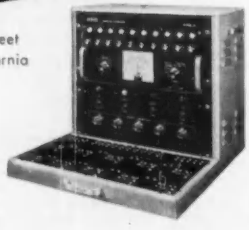
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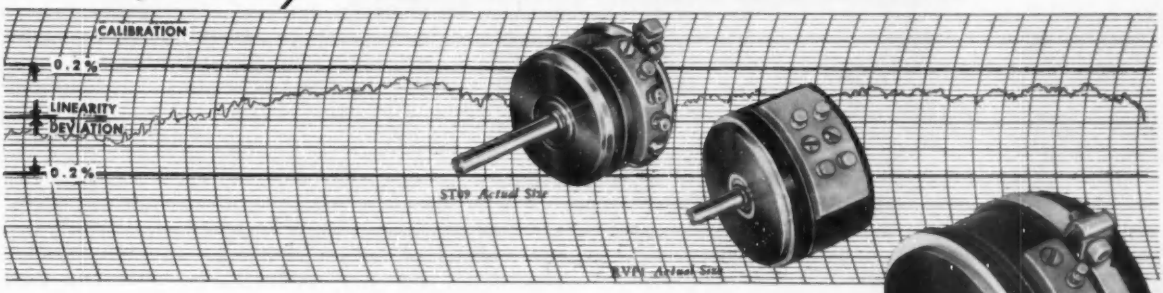


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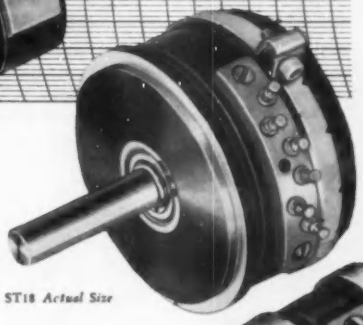
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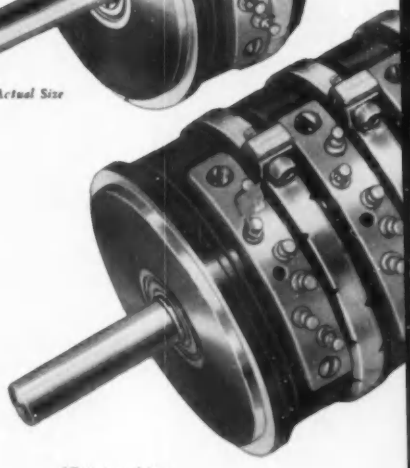


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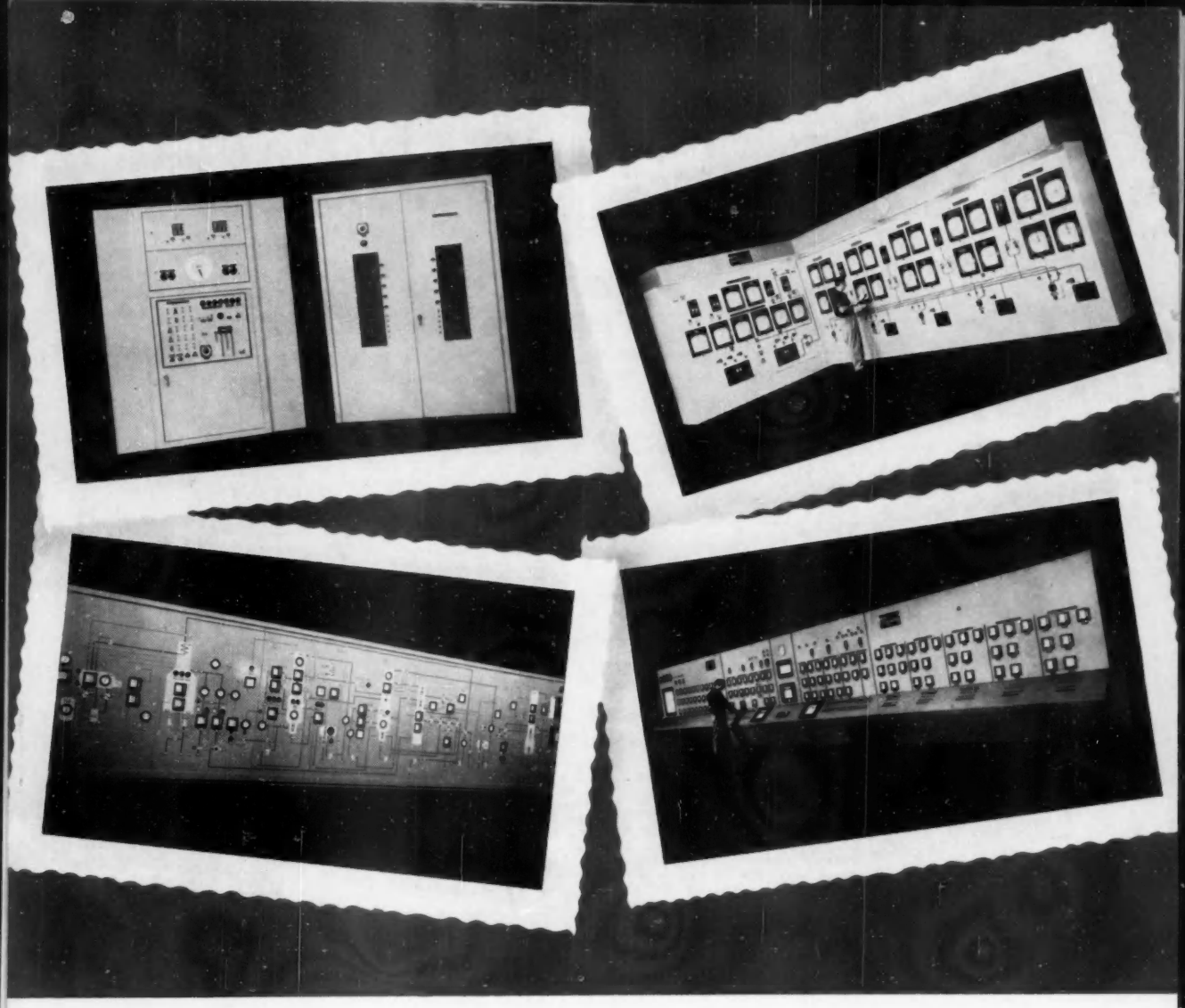
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